Digital Photogrammetric System

PHOTOMOD

Version 5.21

USER MANUAL

Aerial Triangulation

RACURS

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1. Aerial triangulation data

After project creation and block forming (when project images are loaded and adjusted) you can proceed to *data collection* for creating of strip or block *aerial triangulation* networks. Once all necessary initial data is collected, you can perform block adjustment (see **Block adjustment** User Guide). The result of images block creation and adjustment is determination of images exterior orientation parameters, which are used for further photogrammetric processing (see **Project processing** User Guide).

Use the following data to perform aerial triangulation:

- interior orientation parameters – determine location and orientation of image coordinate system in relation to digital image coordinate system. Images interior orientation is *obligatory stage*.
- Relative orientation parameters – results of triangulation points measurements on images of a block.
- Results of ground control points measurement on images of a block (see also the chapter Input and measuring of ground control points).
- Exterior orientation parameters, measured by GPS/IMU on-board systems. Exterior orientation parameters are *coordinates of projection centers and 3 angles* that together determine real images location in space. If you have exterior orientation parameters you can import them (see the chapter Import of exterior orientation parameters). In case of satisfying accuracy of imported exterior orientation

parameters, proceed immediately to processing stage – stereovectorization, DEM building, orthomosaic creation (see **Project processing** User Guide). Otherwise, you should define more exactly images location in space using tie points (i.e. perform Relative orientation), as well as using ground control points.

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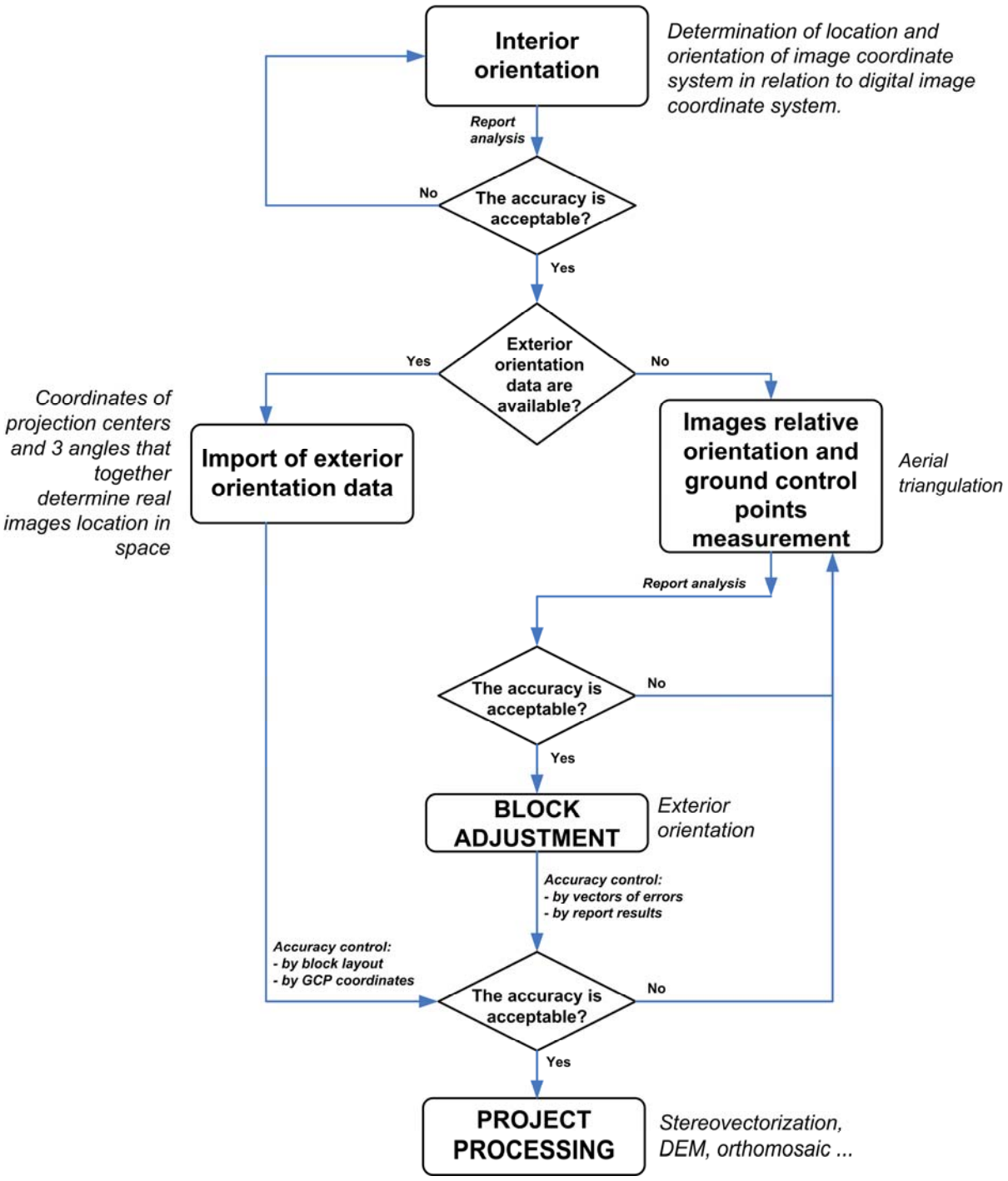
2. Workflow

Workflow: data collection for creating of strip or block aerial triangulation networks



If the on-board exterior orientation data is unavailable, the task of data collection for block adjustment turns into *aerial triangulation,* which includes:

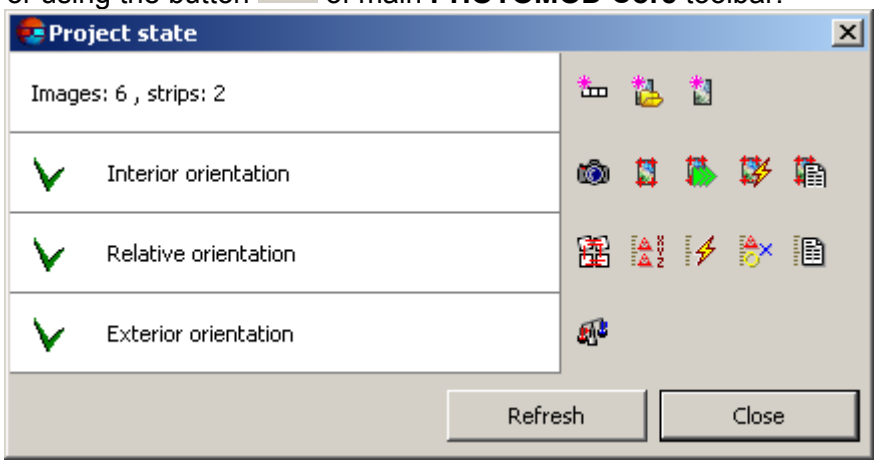
- input and measuring of ground control points
- images relative orientation
- measuring of tie points on stereopairs and in triplets;
- measuring of inter-strip tie points.

After executing of each stage of data collection for aerial triangulation you should perform control of measurements accuracy and errors elimination. See the chapter Control of stages performing.

2.1 *Control of stages performing*

You can control data collection for exterior orientation (block adjustment) using the following features:

- *Project state summary* window, opened using menu command **Project | Project state** or using the button of main **PHOTOMOD Core** toolbar.



Project state summary window

Project state summary allows viewing project state as a whole. Completed project stages are marked by symbol , partly accomplished – , unperformed stages – .

Tools for opening of different dialogue window used for project processing are provided for each project stage. The **Project state** window shows:

– state of block forming stage (number of strips and images) and tools for adding of images and strips to a project. See the chapter **Block forming** in **Project creation** User Guide;

– state of interior orientation stage and tools for specifying of project cameras, interior orientation executing and viewing of resulting report. See the chapter Interior orientation;

– state of relative orientation stage and tools for block layout creation, relative orientation executing and viewing of resulting report. See the chapter Relative orientation and ground control points measurement;

– state of exterior orientation stage and tool for block adjustment. See **Block adjustment** User Guide.

- *Detailed reports on interior and relative orientation* to check results of aerial triangulation and control of measurements accuracy. (See the chapters Report on interior orientation and Relative orientation report).

- *Block layout* – to implement visual control using block scheme that is created considering existed data or data collected during project processing: overlap areas

sizes, manual or automatic feature matching data, imported exterior orientation parameters, tie and GC points measurements, etc. See the chapter Block layout.

3. Interior orientation

The interior orientation procedure is used to find the position and the orientation of film coordinate system relatively to coordinate system of digital image. Besides, during interior orientation the parameters describing a systematic film distortion can be found.

The parameters defined in the process of interior orientation are used to transform measured image point coordinates from digital image coordinate system to film coordinate system.

Three types of transformation from digital image coordinate system to film coordinate system can be performed during interior orientation. You can apply one of them depending on camera data entered to passport.

If during camera calibration fiducial marks data were measured in camera coordinate system (calibration parameters – **Fiducial coordinates**), you can apply *affine* or *projective* transformations to measured point coordinates, to transform the point coordinates from digital image coordinate system to film coordinate system and correct systematic errors.

Please note, that you should measure at least 3 fiducial marks on image to find affine transformation parameters, and at least 4 fiducial marks to find projective transformation parameters.

If you have measured less than 3 marks (if the rest are invisible, for instance), you can use simple transformation **Rotation**, **scale**, **shift**.

3.1 *Interior orientation menu*

To perform interior orientation use menu command **Orientation | Interior orientation** that includes the following commands:

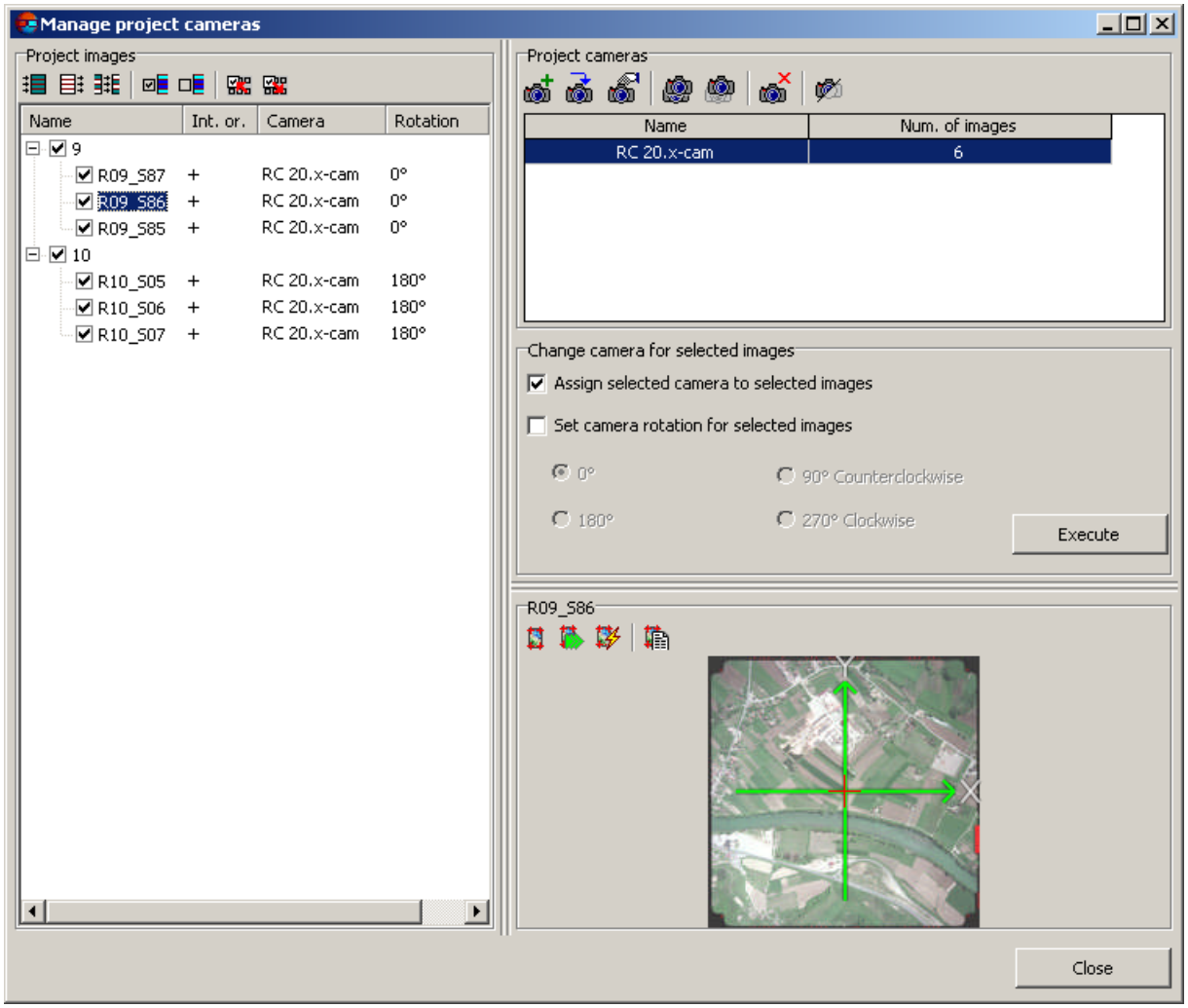
- **Report on interior orientation** – opens report with interior orientation data (duplicated by the button). See the chapter Report on interior orientation.
- **Manual interior orientation** – opens **Interior orientation** dialogue used for manual measuring of fiducial marks if case of film camera (duplicated by the button). See the chapter Manual measuring of fiducial marks.
- **Semiautomatic interior orientation** – opens **Semiautomatic interior orientation** window used for semiautomatic interior orientation that means using of template image with marks-templates and searching for the same fiducial marks on other images of the block, acquired by film camera (duplicated by the button). See the chapter Semiautomatic interior orientation.
- **Automatic interior orientation** – opens **Automatic interior orientation** window used for automatic interior orientation that means automatic recognition of fiducial marks by specified marks type, peculiar to specific film camera (duplicated by the button). See the chapter Automatic interior orientation.
- **Calculate interior orientation** – calculates interior orientation parameters (duplicated by the button).

- **Delete interior orientation data** – opens **Select images** window to remove fiducial marks measurements on selected images.

3.2 *Cameras management*

To perform interior orientation you should specify cameras for images used in a project and input their passport data.
In common case there is a following workflow:
- create cameras list of a project and input their parameters;
- assign cameras to project images;
- specify cameras axes directions for project images.

Manage project cameras window is opened by pushing the button on **AT** toolbar or using menu command **Orientation | Manage cameras**. The window is used for input and editing of cameras parameters, creating of cameras list for current project and assigning of cameras to images from the images list, if images block contains images, acquired by different cameras.



Manage project cameras window

Left part of the window called **Project images** panel contains a list with all strips/images of the project and their parameters, as well as tools for images selection.

You can *select* images using different ways. To select particular images, mark the appropriate checkbox. To select all images of the strip, mark the appropriate checkbox for the strip. There are the following tools for images selection:

- - select all images in the list;
- - cancel all images selection;
- - invert images selection;
- - select *highlighted* images;
- - cancel selection of *highlighted* images;
- - select those images in the list, which are highlighted in block scheme in 2D window;
- - highlight in block scheme in 2D window the images selected in the list.

To *highlight* an image click the image name in the list. The highlighted image is shown in view window in the right part at the bottom. To highlight several images use **Ctrl** and **Shift** keys.

Project images have the following parameters displayed in the list – interior orientation state (+ or -), a name of assigned camera and camera axes rotation angle.

The **Project cameras** panel of the window is used for project cameras management and contains the following:
– tools to input/edit camera parameters and creating of cameras list for current project,
– window with cameras list of current project,
– the **Change cameras for selected images** section used to assign cameras to images and to specify cameras axes directions for selected images,
– view window for the image highlighted in the list.

You can input cameras parameters and create the images list of the current project using the following tools:

- – **New camera**. Opens the **Camera** window used to input camera's passport data. After the input is completed click **OK**. The new camera name is shown in cameras list, and the **Cameras** subfolder, which contains <*Camera name.***x-cam**> file, is created in active profile resources in current project folder. Besides, the **Camera** window provides opportunity to import camera parameters from external files or from active profile resources and to export camera parameters to file/resource. See the chapter Cameras parameters import and export.
- – **Import camera from another project** of *active profile.* Opens the **Open** window displaying *all resources of active profile* to select camera from another project. Select **x-cam**-file in another project folder in **Cameras** subfolder. Click **Open**. The camera selected is shown in the list.
- – **Edit camera** parameters for the camera selected in the list. Opens the **Camera** window to change parameters of camera selected in the list. You can edit all parameters except camera name. Besides, the **Camera** window provides opportunity to import camera parameters from external files or from active profile resources and to export camera parameters to file/resource. See the chapter Cameras parameters import and export.
- – **Copy camera** – to create copy of camera selected in the list. Opens the **Copy the camera** window to input a new name for camera selected. Input a new name or confirm the existing one, then push **OK**. Camera copy is shown in the list.

- – **Rename camera** selected in the list. Opens the **Rename the camera** window. Input a new name or confirm the existing one, then push **OK**. Camera new name is shown in the list.
- – **Delete camera** selected in the list.
- – **Unassign camera for selected images**. At that in cameras list, the **Number of images** column shows ”0” value.

For more details on input of film and digital cameras parameters refer to the appropriate chapters Input and editing of film camera parameters and Input of digital camera parameters.

In window of cameras list you can see names of current project cameras and number of images assigned to particular project cameras.

The **Change camera for selected images** section contains the following options:
- **Assign selected camera to selected images**;
- **Set camera rotation to selected images**.

In order *to assign camera to selected images*:
– select camera in project cameras list;
– select images in в project images list;
– select the **Assign selected camera to selected images** checkbox;
– push the **Execute** button.

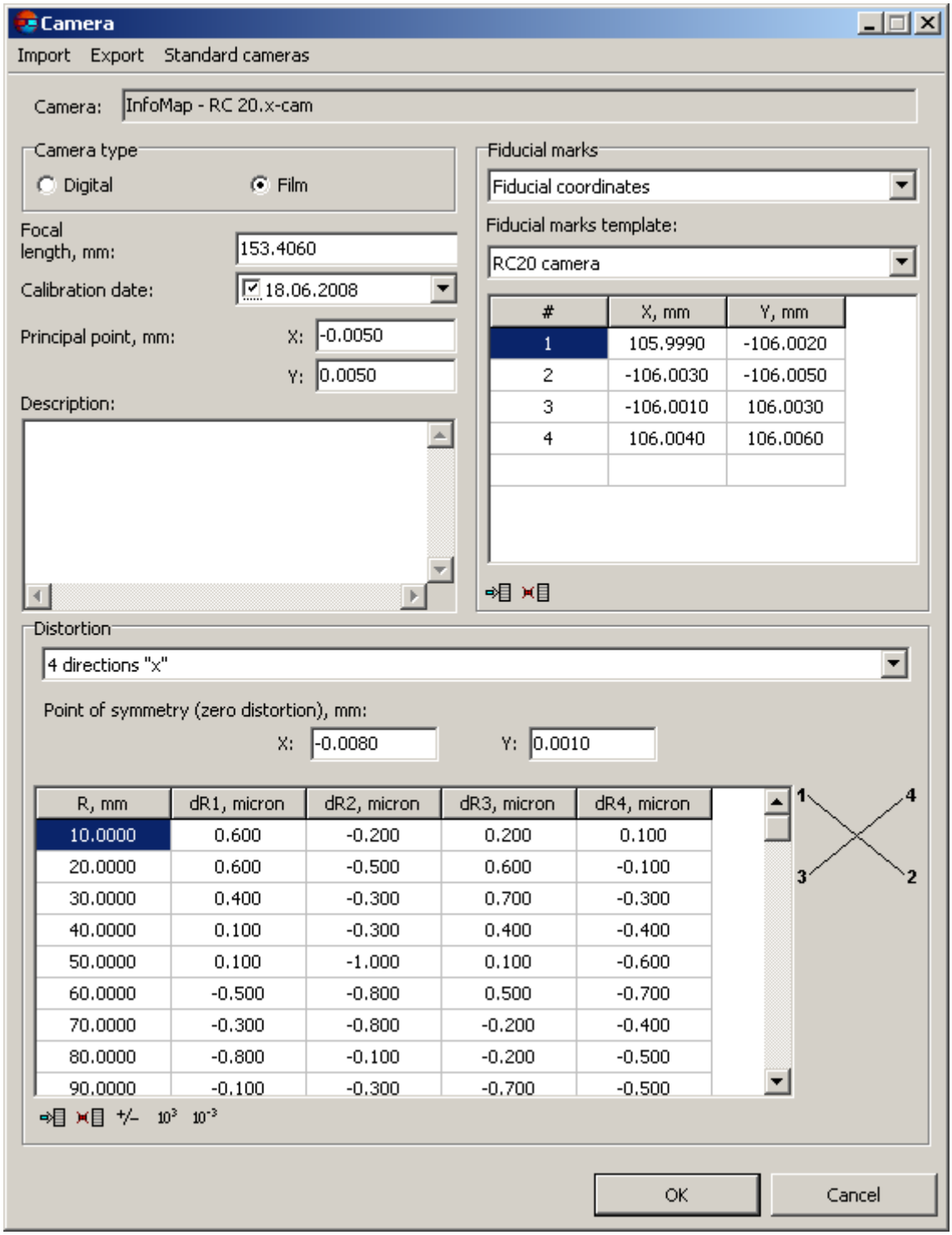
In order *to rotate camera axes* according to passport data:
– *highlight* images in images list of the project, that needed to be rotated (use images view window);
– select the **Set camera rotation to selected images** checkbox and specify a rotation angle;
– push the **Execute** button.

Section for *highlighted* image view contains image name, window for selected image view displaying also camera axes in the image and toolbar used to pass to interior orientation stage and to open interior orientation report.

After specifying of project cameras and assigning cameras to images, you can proceed to interior orientation stage. See the chapter Interior orientation of film camera images or Interior orientation of digital camera images.

3.2.1 Input and editing of film camera parameters

You can input/edit parameters of film camera assigned to a current project using **Manage project cameras** window. Push the button (see the chapter Cameras management) to open the window and then push the button (**New camera**) or (**Edit camera**). In the opened **Camera** window you can fill in or edit the following fields:



Film camera parameters

- **Camera** – input arbitrary name of camera.
- **Camera type** – specify camera type: **film** or **digital** (see the chapter Input of digital camera parameters).
- **Focal length** – input focal length in **mm**.
- **Calibration date** – input date of camera calibration.
- **Principal point** – input principal point coordinates in **mm**.
- **Description** – camera description that is helpful to identify the camera and projects in which it has been used.
- **Fiducial marks** – is selected according to the available camera calibration data:
  - **Principal point only** – is setup by **Xo** and **Yo** coordinates in **mm**. Used for interior orientation, if there are no calibration data and fiducial marks available.

  - **Fiducial marks** – is used for interior orientation, if there are no calibrated fiducial marks coordinates or calibrated distances available, but it is possible to calculate the principal point at the intersection of the segments, joining the fiducial marks.
  - **Calibrated distances** – allows to input calibrated distances between fiducial marks in **mm** on XY axes – **Lx** and **Ly**.
  - **Fiducial coordinates** – allows to input calibrated **X**, **Y** coordinates of the fiducial marks, if they are available in camera passport.
- **Fiducial coordinates type** – if you use calibrated distances and fiducial marks coordinates, you can select fiducial marks type – *fiducial marks-template* from drop-down list, if the list contains suitable camera. Selected template already includes fiducial marks data, specific for selected camera type, – marks numeration, marks template and marks searching area. That is why you can perform interior orientation immediately in automatic mode. See the chapter Automatic interior orientation.

- **Distortion** – is selected according to available camera distortion data in camera passport. In the list opened choose one of the following:
  - **No data** – no distortion data available
  - **Formula** – input a set of Brown-Conrady model coefficients
  - **Radial** – input a set of distortion values depending on distances from the principal point
  - **4 directions "+"** – input a set of distortion values along the axes of the image coordinate system
  - **4 directions "X"** – input a set of distortion values along the diagonal directions
  - **8 directions** – input a set of distortion values along the axes of the image coordinate system and diagonal directions.

When entering the distortion data you should input the **point of symmetry** coordinates (zero distortion point in **mm**) and the distortion data in **microns** in either as a table or a formula.

The screenshot above shows the example of distortion data along diagonal directions. Directions orientation is shown on scheme to the right from distortions table. You should input to each table row: distance from the point of symmetry – radius (first column) and distortion values the distortion values in the other columns corresponding to the different directions. To add, delete or edit lines, use the set of buttons below the table:

- – **Add line** to the table (**Ctrl-Ins** shortcut);
- – **Delete line** selected in the table (**Ctrl-Del** shortcut);
- – **Change sign**;
- – **Multiply by 1000** (to multiply distortion value by 1000, use it to put distortion values in the table to **microns**);
- – **Divide by 1000** (to divide distortion value by 1000, use it to put distortion values in the table to **microns**).

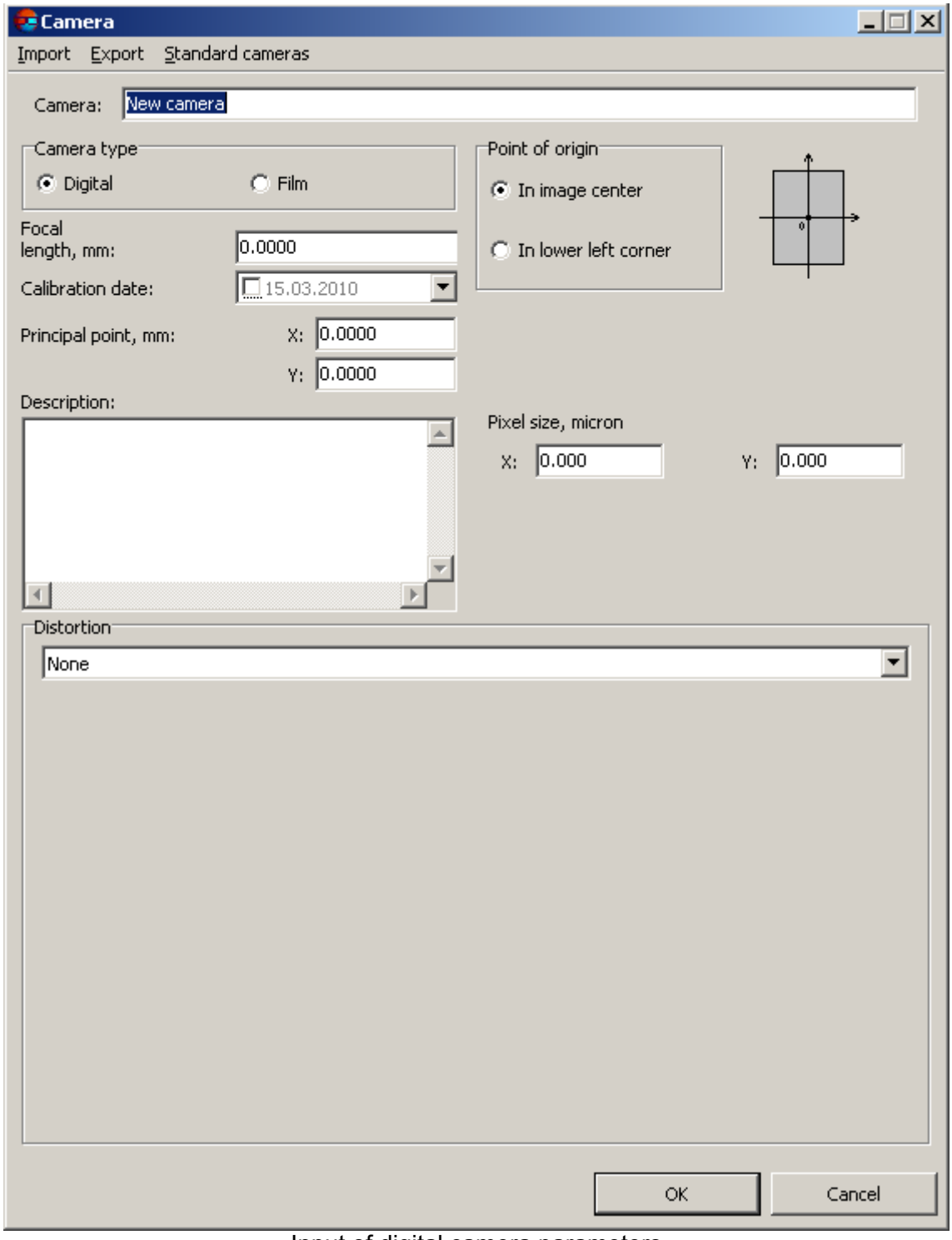
Note. Positive distortion coefficients mean image "shift" from center

3.2.2 Input of digital camera parameters

You can input/edit parameters of digital camera assigned to a current project using **Manage project cameras** window. Push the button (see the chapter Cameras management) to open the window and then push the button (**New camera**) or (**Edit camera**). In the

opened **Camera** window input the camera name to appropriate field. In **Camera type** field specify camera type – **digital**.
When input digital camera parameters remember that all of them (principal point coordinates, focal length, point of symmetry (zero distortion point)) should be input in **mm**, but pixel size and distortion coefficients – in **microns**.

In **Point of origin** section specify a *point of origin* position, used to calculate a shift of a principal point and a point of symmetry to consider a distortion from camera passport:
– **in lower left corner** – in center of lower left pixel;
– **in image center**.



Input of digital camera parameters

The example below shows digital camera (DSS) parameters input.

DSS Camera passport

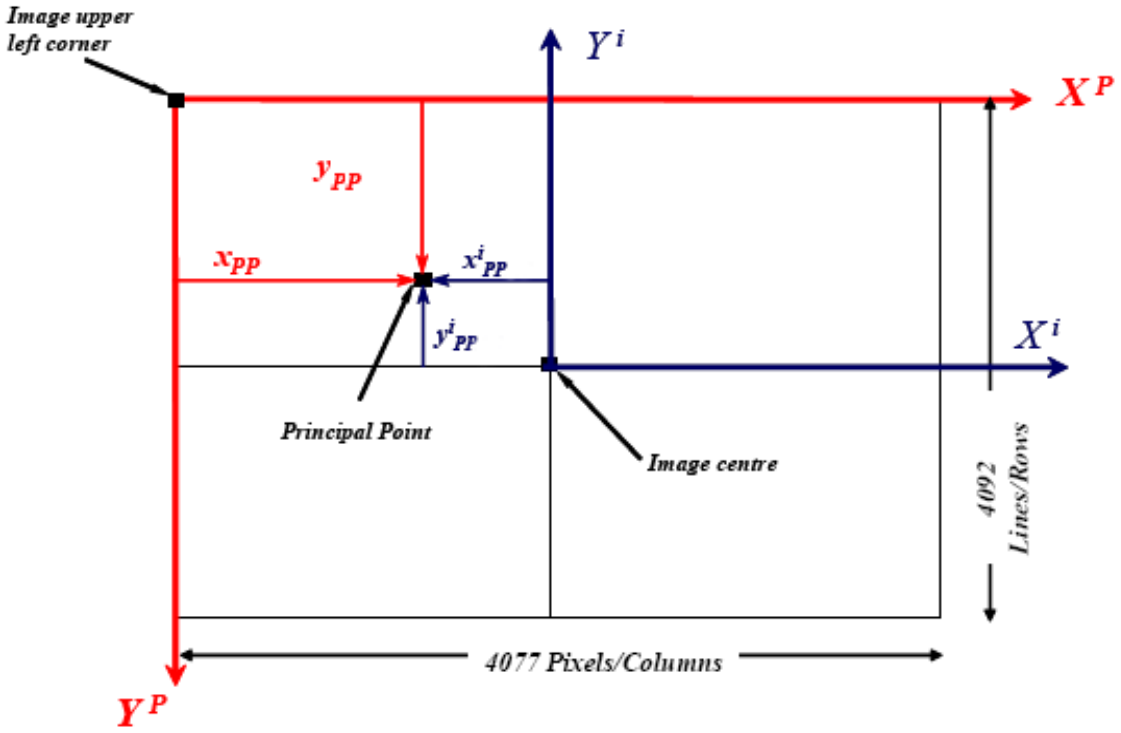
Table 1. Camera Calibrated Parameters

Parameter	Value
f (mm)	54.995
x_{PP} *(pixels)* [+]	2011.49
y_{PP} *(pixels)* [+]	2018.91
x_{PP}^{C} *(mm)* [++]	-0.243
y_{PP}^{C} *(mm)* [++]	0.244

[+] x_{PP} and y_{PP} are measured from image upper left corner, (image size 4077x4092), see Fig.8
[++] x_{PP}^{C} and y_{PP}^{C} are measured from image center (pixel size = 9 microns), see Fig.8

Table 2. Radial Lens Distortion

Radial Distance (mm)	Radial Distortion (Pixel)	Radial Distortion (microns)
1	-0.00	-0.022
2	-0.02	-0.180
3	-0.07	-0.607
4	-0.16	-1.441
5	-0.31	-2.833
6	-0.54	-4.897
7	-0.86	-7.783
8	-1.29	-11.589
9	-1.84	-16.571
10	-2.53	-22.747
11	-3.37	-30.287
12	-4.37	-39.313
13	-5.55	-49.937
14	-6.93	-62.376
15	-8.50	-76.486
16	-10.27	-92.419
17	-12.22	-110.024
18	-14.42	-129.783
19	-16.79	-151.116
20	-19.34	-174.056
21	-22.04	-198.395
22	-24.87	-223.839
23	-27.80	-250.233
24	-30.73	-276.592
25	-33.61	-302.506
26	-36.35	-327.179



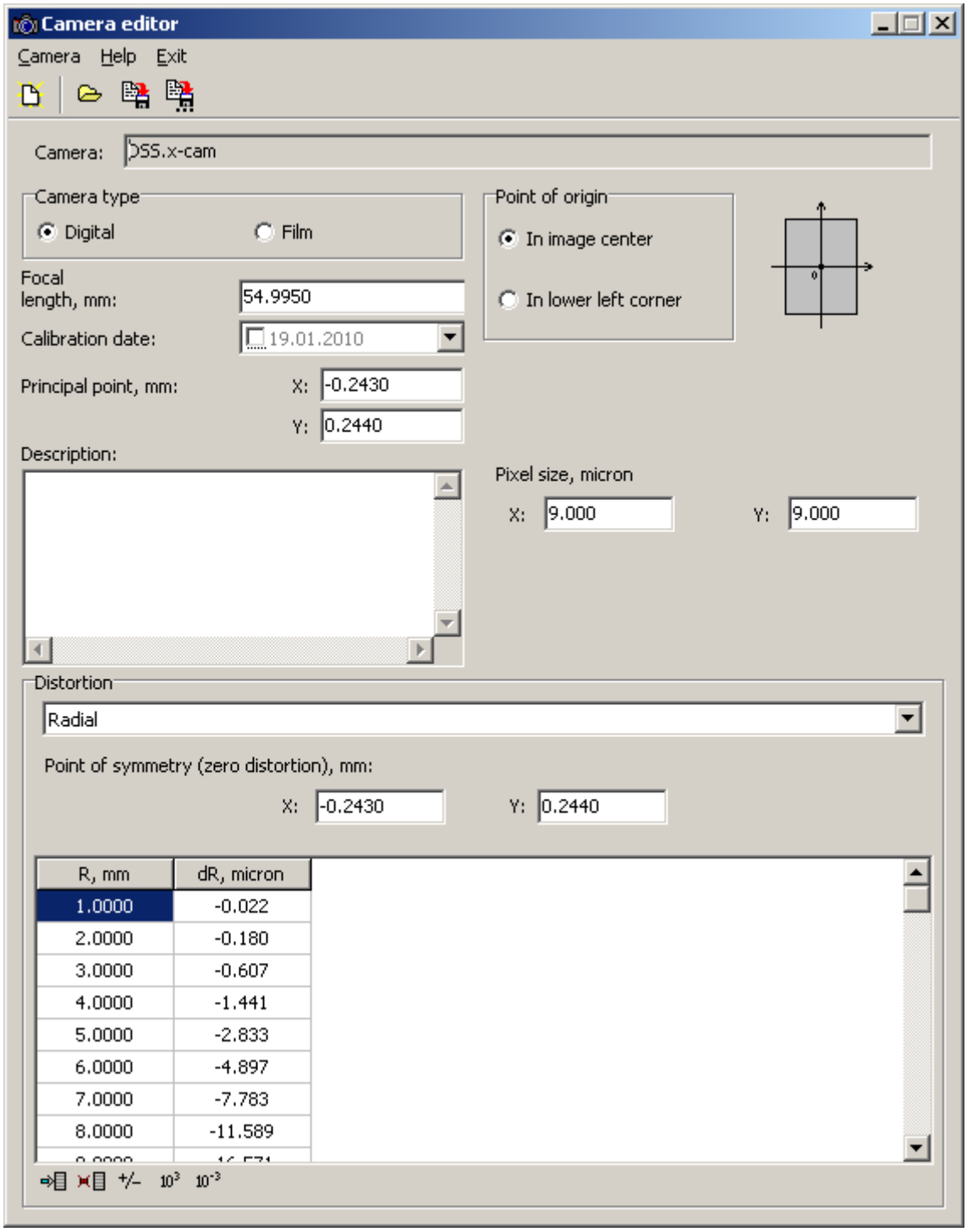
Notation:

X^i and Y^i: Image Coordinate Frame – **Right** Handed System
X^P and Y^P: Pixel/Monitor Coordinate Frame – **Left** Handed System

Point Offsets in a DSS Digital Image

Note. In given example, symmetry point (with zero distortion) coincides with the principal point

In **Cameras** window input the following values:



Input parameters of DSS digital camera

- **Camera type** – *Digital*
- **Point of origin** – *in image center*
- **Pixel size** – *9* ***micron***
- **Focal length** – *54.995* ***mm***
- **Principal point** (shift of principal point coordinates from image center):

  X = x^i_{pp} = *- 0.243* ***mm***

  Y = y^i_{pp} = *0.244* ***mm***
- **Symmetry point** (coordinates of zero distortion) in **Distortion** section (the same as principal point coordinates):
- **X=** *- 0.243 mm*,
- **Y=** *0.244 mm*

- **Radial distortion** – according to camera passport

Note. Survey should be performed with the same camera resolution and focal length, that were used during camera calibration (if camera allows to perform survey with different resolutions).

After you have completed correct input of digital camera parameters, you can immediately perform interior orientation. See the chapter Interior orientation of digital camera images.

3.2.3 Cameras parameters import and export

You can import camera parameters from **x-cam**-file of file system or from active profile resources.

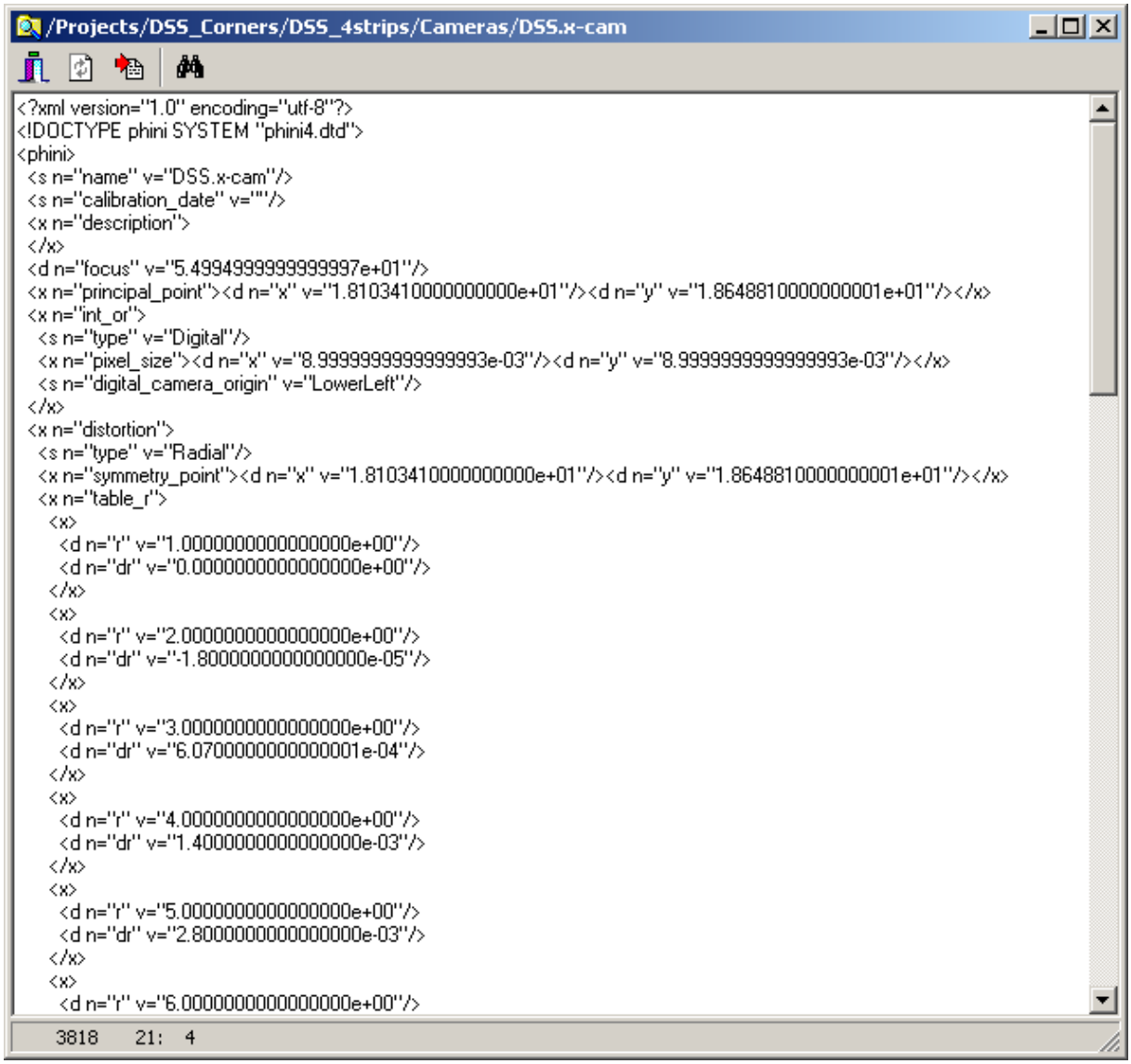
To start camera parameters import from files/resources open the **Camera** window from Cameras management window, using the button (**New camera**) or (**Edit camera**), and select menu commands **Import | From file** or **Import | From resource**.

In case of importing from file, the **Load camera** window is opened. You should select necessary file with camera parameters (with **x-cam** extension) on local/network disks (i.e. exterior file, which is not a resource of active profile) and push **OK**. All parameters of selected camera will be loaded to appropriate fields.

In case of importing from file, the **Open** window is opened, where you can see a tree of active profile resources. Select the file from resources with camera parameters (with **x-cam** extension) and push **OK**. Files with cameras parameters are stored by default in **Cameras** folder in each profile project. All parameters of selected camera will be loaded to appropriate fields.

To perform camera parameters export select menu commands **Export | To file** or **Export | To resource** in **Camera** window.

File with ***.x-cam** extension has contents as follows:



Camera parameters file format **x-cam**

The **x-cam**-file contains fields corresponding to the **Camera** dialogue parameters: Name – camera name; CalibrationDate – date of calibration; Description – camera description; Focus – focal length; PrincipalPoint – principal point's coordinates, etc.

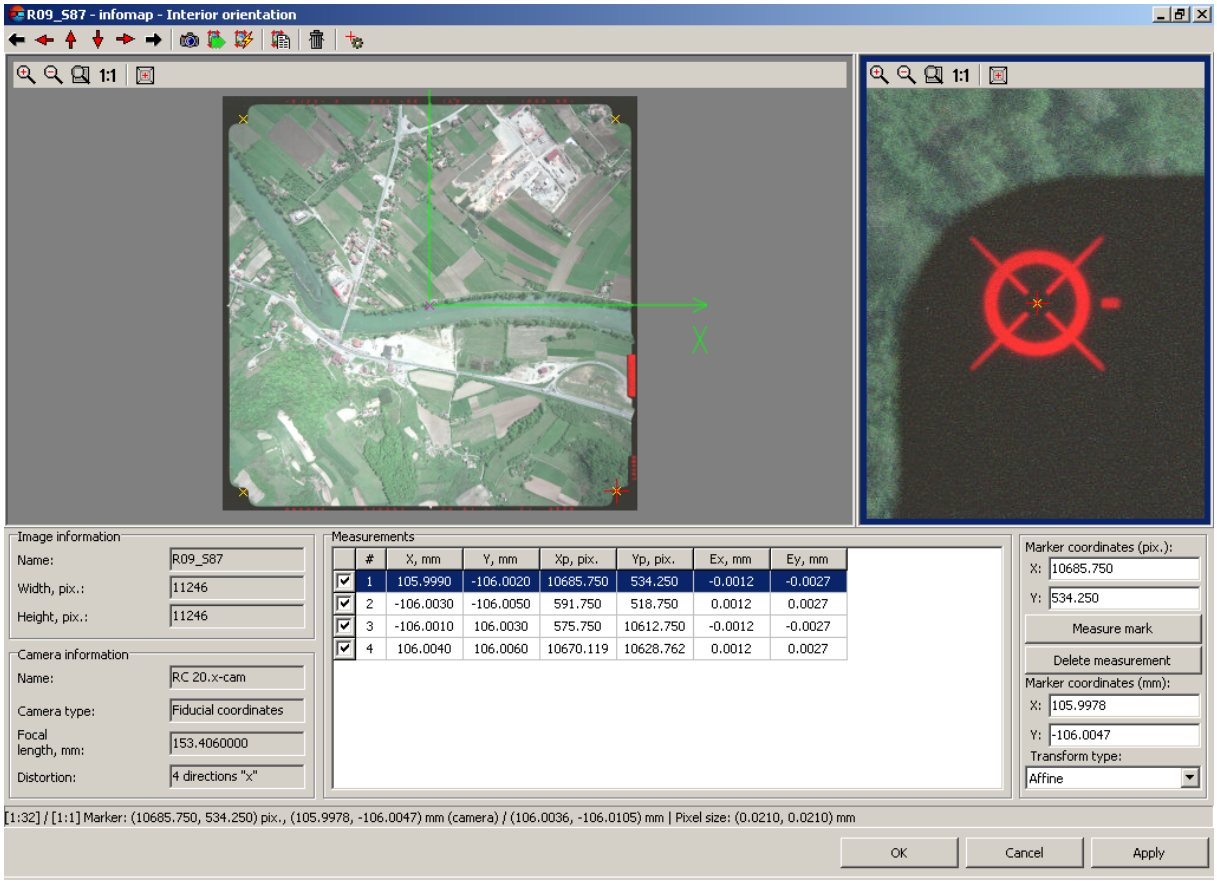
See also the chapters Input and editing of film camera parameters and Input of digital camera parameters.

3.3 *Interior orientation of film camera images*

You can use three methods of interior orientation of images assigned to film camera (see the chapters Cameras management and Input and editing of film camera parameters):
- measure fiducial marks manually and perform interior orientation (see the chapter Manual measuring of fiducial marks);
- perform interior orientation in semiautomatic mode using a template image, which has already measured fiducial marks and interior orientation completed (see the chapter Semiautomatic interior orientation);
- perform automatic interior orientation, if camera parameters contain *Fiducial coordinates type* specified, which includes data on fiducial marks location, templates and numeration (see the chapter Automatic interior orientation).

3.3.1 Manual measuring of fiducial marks

After you have specified film cameras for project images you can proceed to stage of fiducial marks measuring (if any) and in that way perform images interior orientation.
For manual measuring of fiducial marks on image you should select the image in **Block scheme window** and push the button (or use menu command **Orientation | Interior orientation | Manual interior orientation**). The **Interior orientation** window used for fiducial marks measuring appears. You can also open this window from the **Manage project cameras** window (see the chapter Cameras management).



Fiducial marks measuring

The toolbar at the upper part of the window allows to perform the following operations:

- - to switch to adjacent image in the block - left, up, down or right;
- – to switch to previous or next unmeasured image;
- - opens **Manage project cameras** window;
- - opens **Semiautomatic interior orientation** window;
- - opens **Automatic interior orientation** window;
- – opens **Report on interior orientation**;
- – to delete all fiducial marks measurements on current image;
- – opens **Marker settings** window allowing to adjust shape, size and color of marker.

In **Image information** and **Camera information** panels you can see general information on the image and camera parameters.

In status bar you can always see the scale of the image shown in main window or “lens”-window and marker coordinates (in pixels). When you have measured 2 fiducial marks, the status bar will show also the marker coordinates on the image (in mm)/ the marker coordinates on the image (in mm) *considering distortion* and pixel size (in mm).

Scroll bars in main window and "lens"-window are turned on and off with **Ctrl-F8** hotkey.

The procedure of fiducial marks measurement and interior orientation perform

Select image using the buttons . The table with (X, Y) coordinates of fiducial marks in millimeters taken from camera passport will be shown at the lower part of the window. After interior orientation is completed for cameras with known fiducial marks coordinates, the table will show fiducial marks coordinates Xp and Yp (in pixels) and residual errors of fiducial marks coordinates Ex and Ey (in mm).

To measure fiducial marks you should select a fiducial mark to be measured in fiducials table. Then place the marker precisely on the selected fiducial mark on the image. Marker position coordinates in pixels are shown in **Marker coordinates (pix.)** section. Marker position coordinates in millimeters are shown in **Marker coordinates (mm)** section. For searching fiducials on image and precise marker position use the buttons of upper toolbars in images view windows:

- image zoom out (duplicated by the */* key);

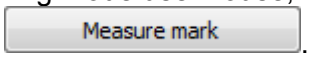
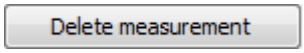
- image zoom in (duplicated by the * key);

- fit image to window (duplicated by **Alt-Enter** shortcut);

- show image in original size 1:1 (duplicated by **Alt-1** shortcut);

- center image on marker.

To move image in the window in panning mode use mouse, holding pressed **Alt** key.

To *fix measurement* push the button  . After that you will see the result of measurement in the **Measurements** table – fiducial mark coordinates Xp and Yp (in pixels). Use the button  to delete measurement.

Once first two fiducial marks have been measured the marker is automatically positioned approximately at the 3-d and subsequent fiducial marks. At that the marker is placed in a neighborhood of a next mark on the image.

When 2 fiducial marks have been measured you can see the following *in status bar*: *information on pixel size*, marker coordinates on the image in pixels and in millimeters, and marker coordinates measured considering distortion (in mm).
After all fiducial marks on the image have been measured you should select a transformation type to be applied.

Select one of transformation types from a list in **Transform type** panel:

- Rotation, scale, shift;
- Affine;
- Projective.

See also the chapter Interior orientation.

Push the button to perform interior orientation.

As a result of interior orientation you can see residuals values Ex and Ey (in mm) between input and measured coordinates in fiducials table. Acceptable value of maximal residual error should not exceed a pixel size. You can perform accuracy control and obtain more details on interior orientation results of the image by pushing the button which allows to view a report on interior orientation. See also the chapter Report on interior orientation.

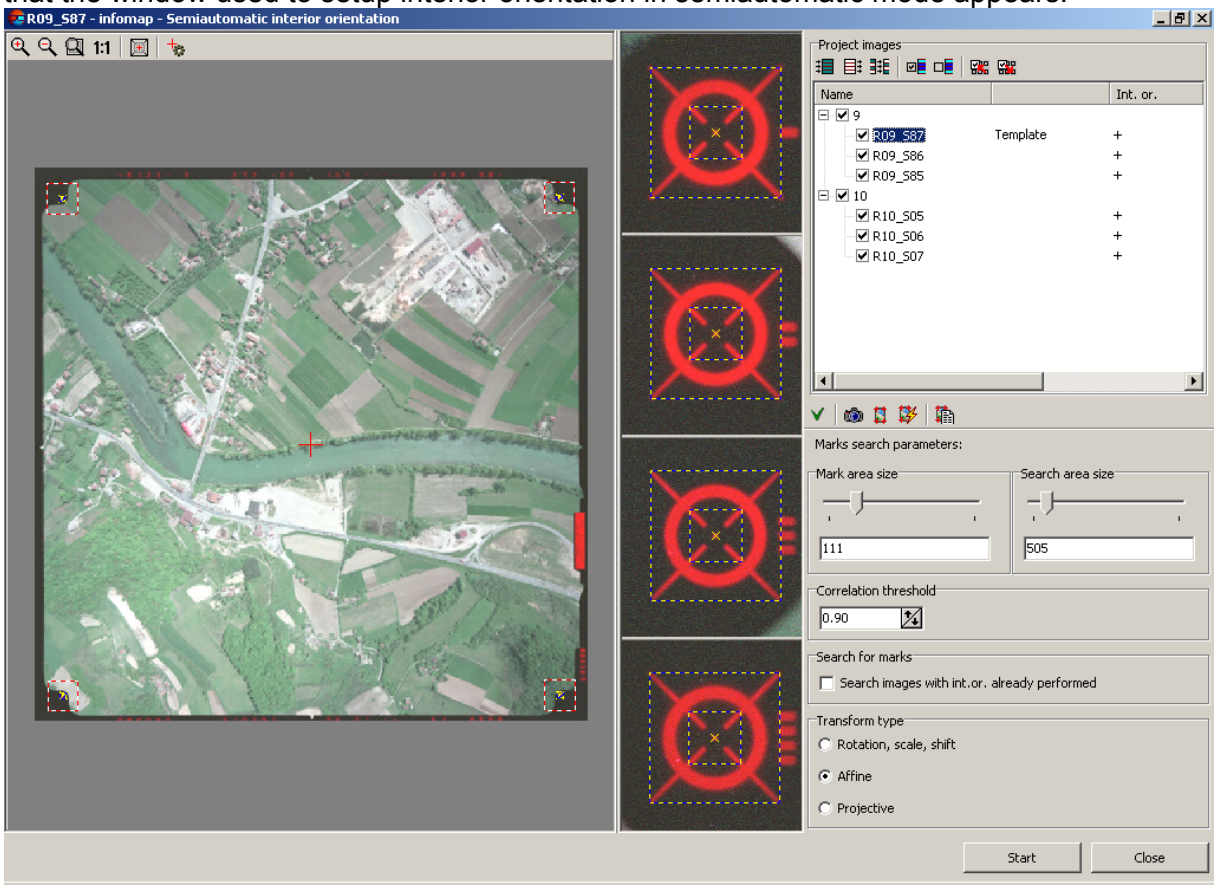
When you have finished fiducial marks measurement *on at least one of the block images*, you can perform interior orientation for the rest of images in semiautomatic mode. See the chapter Semiautomatic interior orientation.

3.3.2 Semiautomatic interior orientation

Before starting semiautomatic interior orientation process you must perform manual interior orientation *at least for one image* (see the chapter Manual measuring of fiducial marks).

Algorithm of semiautomatic interior orientation searches/measures fiducial marks on project images according to selected *template* (the image with already performed interior orientation, which fiducial marks are used as *templates*), and then calculates interior orientation according to selected transformation type.

To perform semiautomatic interior orientation mode push the button or use menu command **Orientation | Interior orientation | Semiautomatic interior orientation**. After that the window used to setup interior orientation in semiautomatic mode appears.



Semiautomatic interior orientation window

The first image with performed interior orientation is marked in the list as **Template**. If there are other images with performed interior orientation you can select another template. To do

this, *select* the image by clicking its name and push the button . You will see the **Template** note to the left from the image name in the table.

Then setup 2 parameters for marks searching – **Mark region size** and **Search region size**, using corresponding sliders.

Search region size should be big enough to “cover“ fiducial mark area especially in cases of cutting or scanning film images differently (when corresponding fiducial marks are located at different distances from the image edge). *Mark region size* defines mark’s template and must include the mark completely. *Search region* and *Mark region* are displayed by rectangles (one external and two internal for the mark), in the “lens“-window and in the main view window as well.

To define searching areas use the buttons of upper toolbar in images view window:

- image zoom out (duplicated by the */* key);

- image zoom in (duplicated by the * key);

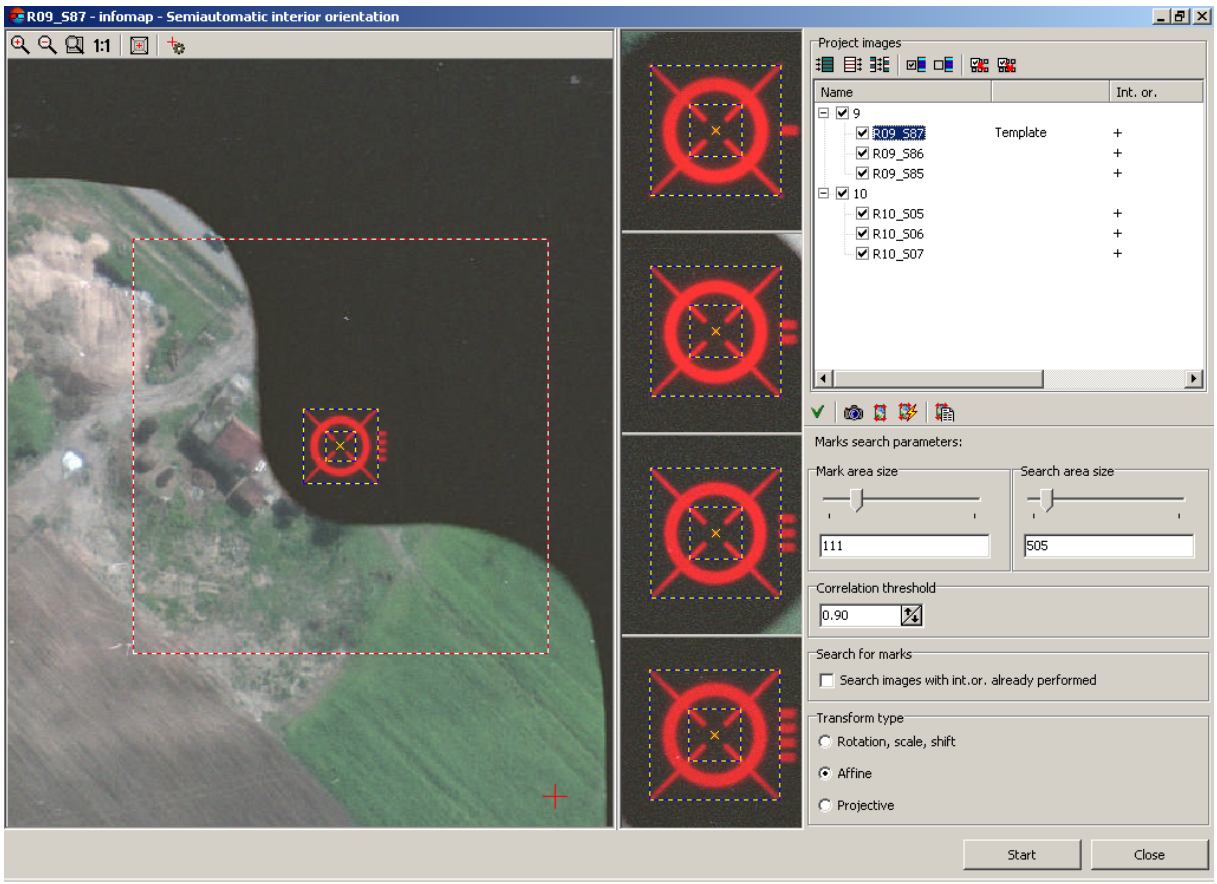
- fit image to window (duplicated by **Alt-Enter** shortcut);

- show image in original size 1:1 (duplicated by **Alt-1** shortcut);

- center image on marker.

You can adjust marker parameters (size, shape, color) in appropriate window opened using the button of upper toolbar.

To move image in the window in panning mode use mouse, holding **Alt** key. Also, scrollbars may be used which are shown and hidden with **Ctrl-F8** hotkey in main window and "lens"-windows.



Specifying of marks searching area and mark template

Semiautomatic interior orientation means searching of the same (by the mark template) objects – fiducial marks on selected images of the block.

The system is looking for fiducial marks using a correlation process, which compares a mark image with a template. Acceptable correlation coefficient threshold is set by the **Correlation coefficient** parameter (0.85 by default).

Section **Search for marks** is used to define images on which the system will search for marks and measure them. There are the following options:
- search for marks **on *selected* images only**.
- search for marks **on all project images**.

Select **Search images with int. or. already performed** checkbox to include into the search those images, which already have interior orientation performed, i.e. to recalculate their interior orientation according to selected *template*.

To *select* images in the list of **Project images** section check boxes to the left from image/strip name or use upper toolbar buttons that allows the following:

- select all images in the list (button);

- cancel all images selection in the list (button);

- invert images selection (button);

- select highlighted images (button);

- cancel highlighted images selection (button);

- select images in the list, selected in block scheme in 2D window (button);

- selected in block scheme in 2D window the images selected in the list (button).

In order to *select* an image click image's name in the list. To select several images hold **Ctrl** and **Shift** keys.

After images selection you should specify one of the following transformation types:
- Rotation, scale, shift;
- Affine;
- Projective.

See also the chapter Interior orientation.

To perform semiautomatic interior orientation, push the button **Start**. You can perform accuracy control and obtain more details on results of image interior orientation by pushing the button which allows to view a report on interior orientation. See also the chapter Report on interior orientation.

Semiautomatic interior orientation window also contains buttons used to open the following windows:

- Cameras management (the button);

- Manual measuring of fiducial marks – manual measuring of fiducial marks (the button);

- Automatic interior orientation (the button).

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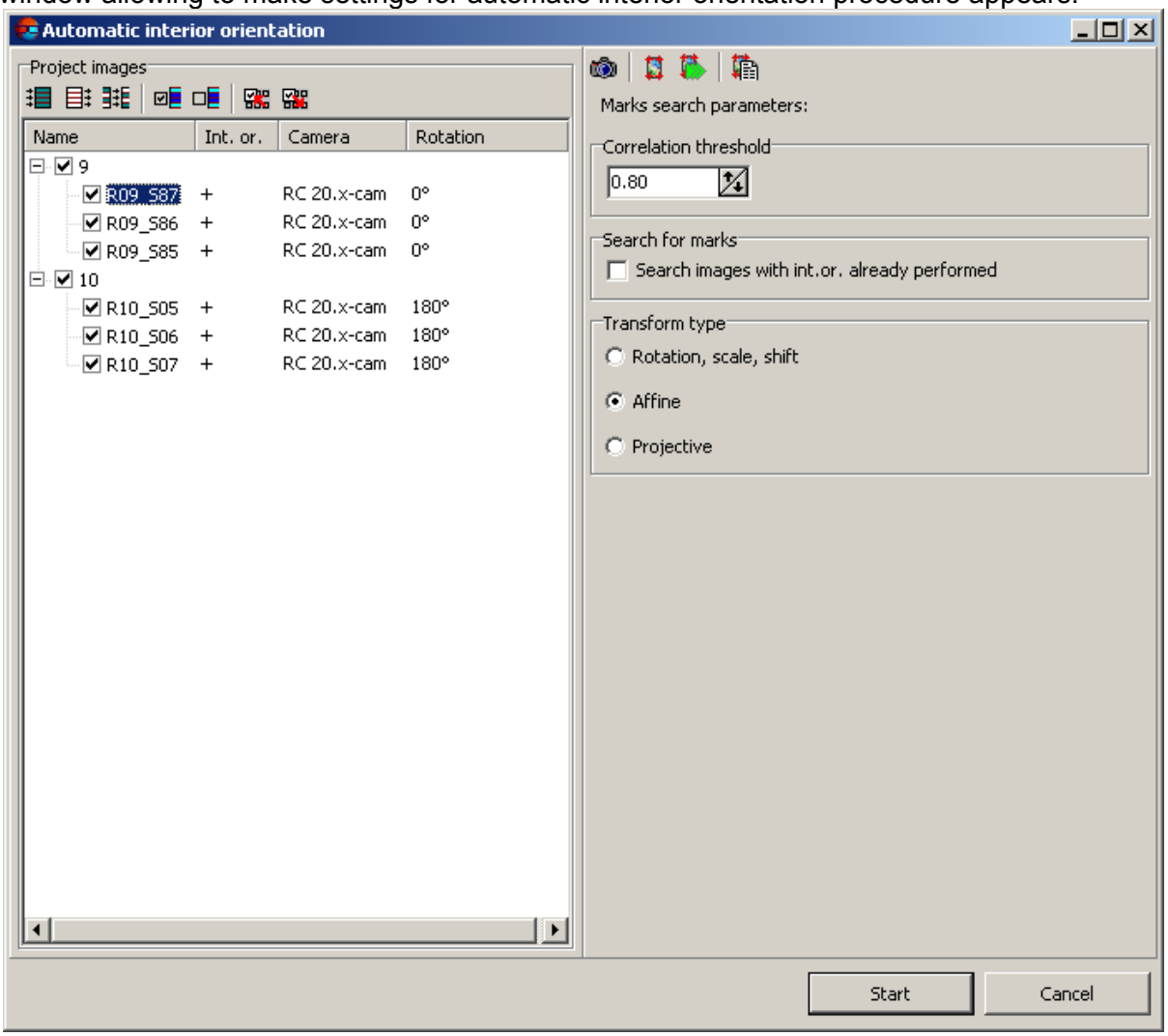
3.3.3 Automatic interior orientation

You can perform automatic interior orientation of images acquired by film camera, if **Fiducial coordinates type** is specified in the camera's parameters. See the chapter Input and editing of film camera parameters. To perform correct automatic interior orientation you should specify correct camera's axes orientation for images. See the chapter Cameras management.

Algorithm of automatic interior orientation searches/measures fiducial marks on project images automatically in accordance with specified *fiducial coordinates type*, and interior orientation measuring. Abovementioned parameter **Fiducial coordinates type** already contains an information on fiducial marks, specific for camera selected, – marks numbering, mark template and marks searching area. The current system version supports fiducial coordinates types for the following cameras: RC 20, RC 30 and LMK.

To perform automatic interior orientation click the button on toolbar or use menu command **Orientation | Interior orientation | Automatic interior orientation**. After that the window allowing to make settings for automatic interior orientation procedure appears.



Automatic interior orientation window

Select images to perform interior orientation. Right part of the **Project images** window contains a list of all project strips and images, and tools for images selection.

To *select* image in the list, check box to the left from the image or strip name (in the latter case you will select all images of selected strip) or use upper toolbar buttons that allows to do the following:

- - select all images in the list;
- - cancel all images selection in the list;
- - invert images selection;
- - select *highlighted* images;
- - cancel *highlighted* images selection;
- - select images in the list, selected in block scheme in 2D window;
- - selected in block scheme in 2D window the images, selected in the list.

In order to *select* an image click image's name in the list. To select several images hold **Ctrl** and **Shift** keys.

Upper toolbar of the left part of the window contains buttons used to open the following dialogues:
- Cameras management, where you can control camera's axes direction on images and adjust cameras parameters to perform automatic interior orientation correctly (the button);

- Manual measuring of fiducial marks for manual measuring of fiducial marks (the button);
- Semiautomatic interior orientation to perform interior orientation in semiautomatic mode (the button);

- Report on interior orientation (the button) to perform quality control of interior orientation procedure.

In the right part of the window you can setup **Mark search parameters**.

Specify correlation coefficient threshold. The system is looking for fiducial marks using a correlation process, which compares a mark image with a template. Acceptable correlation coefficient threshold is set by the **Correlation coefficient** parameter (0.80 by default).

Section **Search for marks** is used to define images on which the system will search for marks and measure them. There are the following options:
- search for marks **on selected images only**.
- search for marks **on all project images**.

Select **Search images with int. or. already performed** checkbox to include into the search those images, which already have interior orientation performed, i.e. to recalculate their interior orientation.

After images selection you should specify one of the following transformation types:
- Rotation, scale, shift;
- Affine;
- Projective.

See also the chapter Interior orientation.

To perform semiautomatic interior orientation, push the button **Start**. You can perform accuracy control and obtain more details on results of image interior orientation by pushing the button which allows to view a report on interior orientation. See also the chapter Report on interior orientation.

If you have obtained unsatisfactory results you can delete interior orientation measurements. To do this, select menu command **Orientation | Interior orientation | Delete interior orientation data**. After that you will see the window allowing to select images where the interior orientation data will be deleted.

3.4 *Interior orientation of digital camera images*

When performing interior orientation of images acquired by digital camera you should input cameras parameters correctly from the camera passport into appropriate fields of **Camera** window. Please remember that all of parameters should be input in the same units in **Camera** window – either in pixels or in millimeters. You should also specify a *point of origin* position, used to calculate a shift of a principal point and a point of symmetry (zero distortion point) – in lower left pixel or in the image center. See the chapter Input of digital camera parameters.

Interior orientation of the image acquired by digital camera means measuring of principal point location regarding to center of left lower pixel of the image.

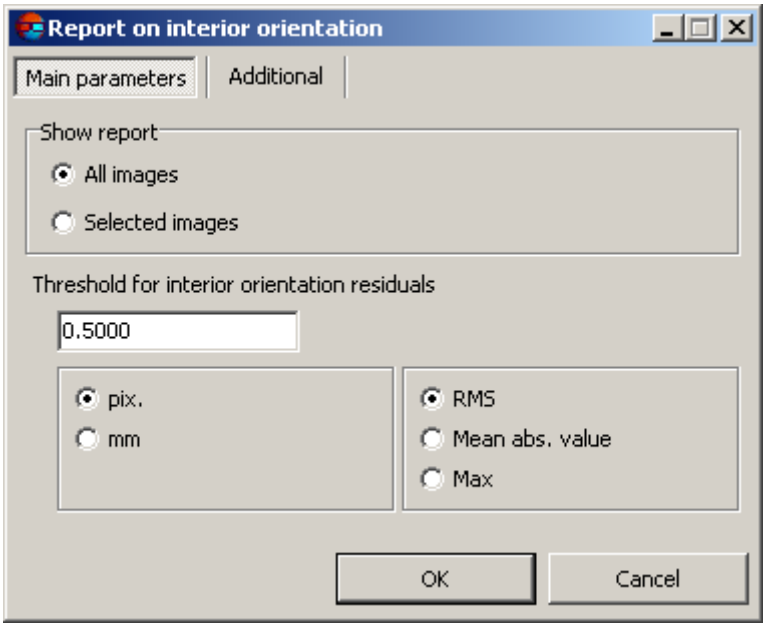
Then you should assign the camera to images and specify camera's axes directions for selected images in Cameras management dialogue window.

To perform interior orientation of images acquired by digital camera click **OK** in **Camera** window. This will start interior orientation operation – calculation of principal point coordinates regarding to lower left pixel center. You can view interior orientation results by pushing the button (Report on interior orientation). You can perform or recalculate interior orientation using the button or menu command **Orientation | Interior orientation | Calculate interior orientation**.

3.5 *Report on interior orientation*

Report on interior orientation provides detailed information about selected parameters and calculation results of interior orientation and allows to keep under control the interior orientation quality.

To view interior orientation report push the button or select menu command **Orientation | Interior orientation | Report on interior orientation**. The **Report on interior orientation** dialogue window is opened.



Main parameters of report on interior orientation

This window contains two tabs where you can setup main and additional parameters.

The **Main parameters** tab is used for specifying the following report parameters:

- Show report for all images or for selected ones
- Setup a threshold on interior orientation residuals for RMS, mean or maximal errors in pixels or mm.

Residuals calculation:

If your images were scanned using photogrammetric scanner, mean absolute value E_{mean} should not exceed a half of pixel. Approximate ratio of mean, maximum error and root mean squared errors:

$$E_{\max} \approx 2 \cdot E_{mean}$$

$$RMS \approx \sqrt{2} \cdot E_{mean}$$

where E_{mean} - mean error, $E_{\max}$ - maximal, RMS - root mean squared error.

The **Additional parameters** tab is used for specifying the additional report parameters:

- Show residuals with fixed point format or in exponential format
- Show residuals with normal, high or maximal precision

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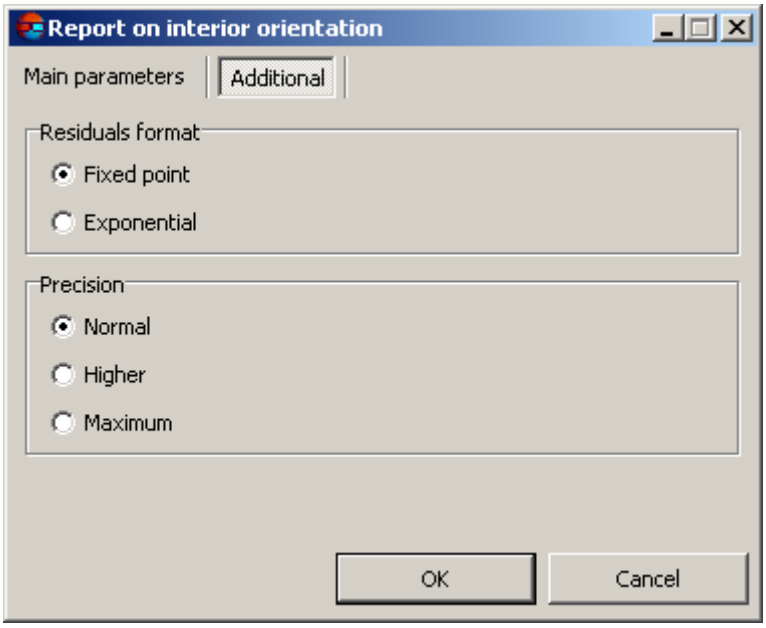
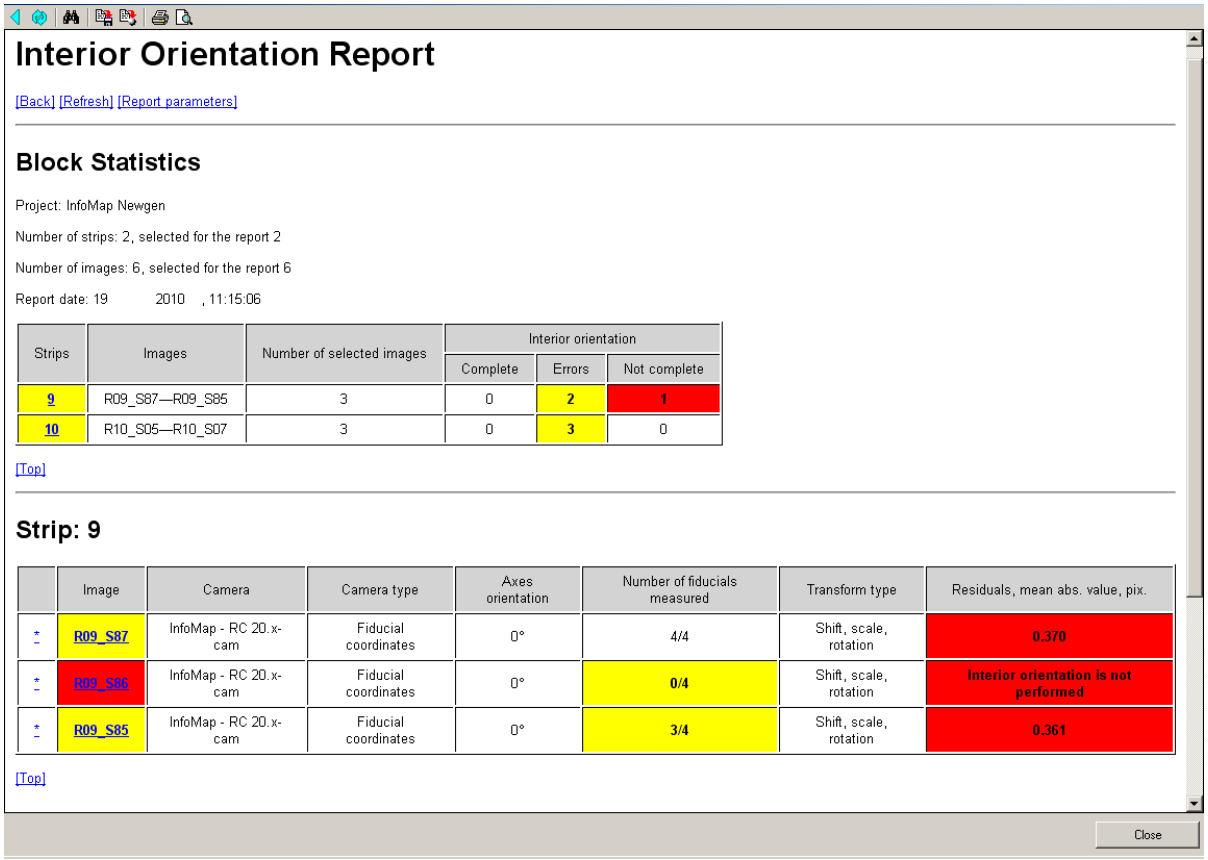


Additional parameters of report on interior orientation

After you click **OK** the report containing general information on interior orientation operation is opened. Here you can see what strips and images are passed interior orientation and what part of the procedure has been completed. There are also shown values of errors of fiducial marks measurements acceptable from specified threshold point of view.



Interior Orientation Report

[Back] [Refresh] [Report parameters]

Block Statistics

Project: InfoMap Newgen

Number of strips: 2, selected for the report 2

Number of images: 6, selected for the report 6

Report date: 19 2010 , 11:15:06

Strips	Images	Number of selected images	Interior orientation		
			Complete	Errors	Not complete
9	R09_S87—R09_S85	3	0	2	1
10	R10_S05—R10_S07	3	0	3	0

[Top]

Strip: 9

	Image	Camera	Camera type	Axes orientation	Number of fiducials measured	Transform type	Residuals, mean abs. value, pix.
*	R09_S87	InfoMap - RC 20.x-cam	Fiducial coordinates	0°	4/4	Shift, scale, rotation	0.370
*	R09_S86	InfoMap - RC 20.x-cam	Fiducial coordinates	0°	0/4	Shift, scale, rotation	Interior orientation is not performed
*	R09_S85	InfoMap - RC 20.x-cam	Fiducial coordinates	0°	3/4	Shift, scale, rotation	0.361

[Top]

Close

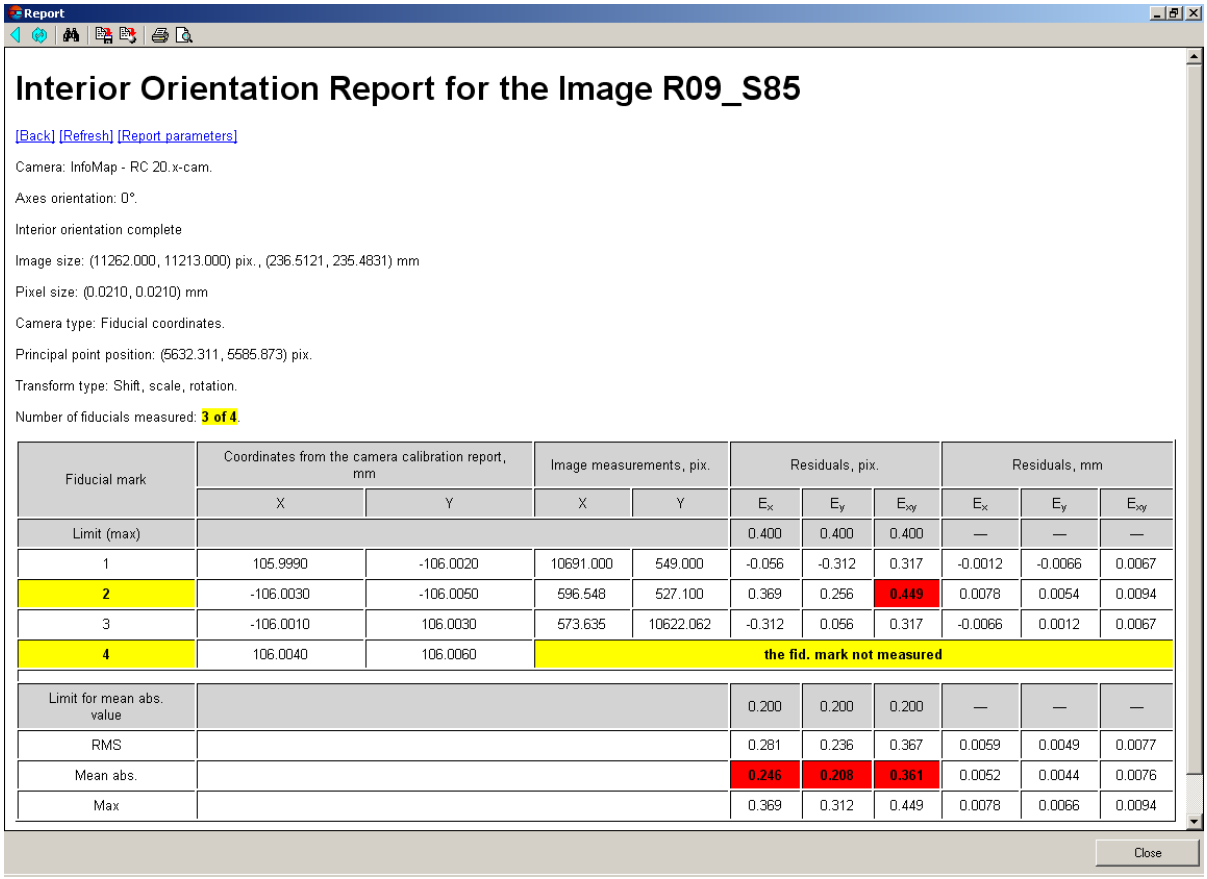
Report on interior orientation for film camera

Strips and images which are not passed interior orientation procedure yet, are highlighted by red color, strips and images, for which interior orientation is done incompletely or with

mistakes, exceeding a threshold, or if not all marks are measured – by yellow. The errors themselves are also marked by red.

The example on the figure above shows unsatisfactory result of interior orientation, where mean error was setup in pixels – 0.2, one of marks on one of images was not measured, and all marks on another image were not measured too.

To proceed to necessary strip select the appropriate link in strips table. In images table of selected strip use a link to pass to detailed information on interior orientation results for the image selected.


Report
Interior Orientation Report for the Image R09_S85
[Back] [Refresh] [Report parameters]
Camera: InfoMap - RC 20.x-cam.
Axes orientation: 0°.
Interior orientation complete
Image size: (11262.000, 11213.000) pix., (236.5121, 235.4831) mm
Pixel size: (0.0210, 0.0210) mm
Camera type: Fiducial coordinates.
Principal point position: (5632.311, 5585.873) pix.
Transform type: Shift, scale, rotation.
Number of fiducials measured: 3 of 4.
Close

Fiducial mark	Coordinates from the camera calibration report, mm		Image measurements, pix.		Residuals, pix.			Residuals, mm		
	X	Y	X	Y	E_x	E_y	E_{xy}	E_x	E_y	E_{xy}
Limit (max)					0.400	0.400	0.400	—	—	—
1	105.9990	-106.0020	10691.000	549.000	-0.056	-0.312	0.317	-0.0012	-0.0066	0.0067
2	-106.0030	-106.0050	596.548	527.100	0.369	0.256	**0.449**	0.0078	0.0054	0.0094
3	-106.0010	106.0030	573.635	10622.062	-0.312	0.056	0.317	-0.0066	0.0012	0.0067
4	106.0040	106.0060	**the fid. mark not measured**							
Limit for mean abs. value					0.200	0.200	0.200	—	—	—
RMS					0.281	0.236	0.367	0.0059	0.0049	0.0077
Mean abs.					**0.246**	**0.208**	**0.361**	0.0052	0.0044	0.0076
Max					0.369	0.312	0.449	0.0078	0.0066	0.0094

Report on interior orientation for an image acquired by film camera

Report on image contains information on camera parameters, including pixel size (mm) and interior orientation data.

Measurements table shows:

- Acceptable maximal error, resulting from specified value in report parameters (if you specified limit for RMS or mean abs., the acceptable maximal error is calculated automatically) in pixels or mm.
- Marks coordinates taken from camera passport in mm – X,Y
- Coordinates of measurements on image in pixels – X,Y
- Values of discrepancies between passport data and measurements in pixels and millimeters – Ex, Ey, Exy
- Residual value specified in the report parameters
- Mean RMS and maximal error values Ex, Ey, Exy in pixels or mm calculated *for all marks*.

The values that exceed acceptable residuals are highlighted by red color.

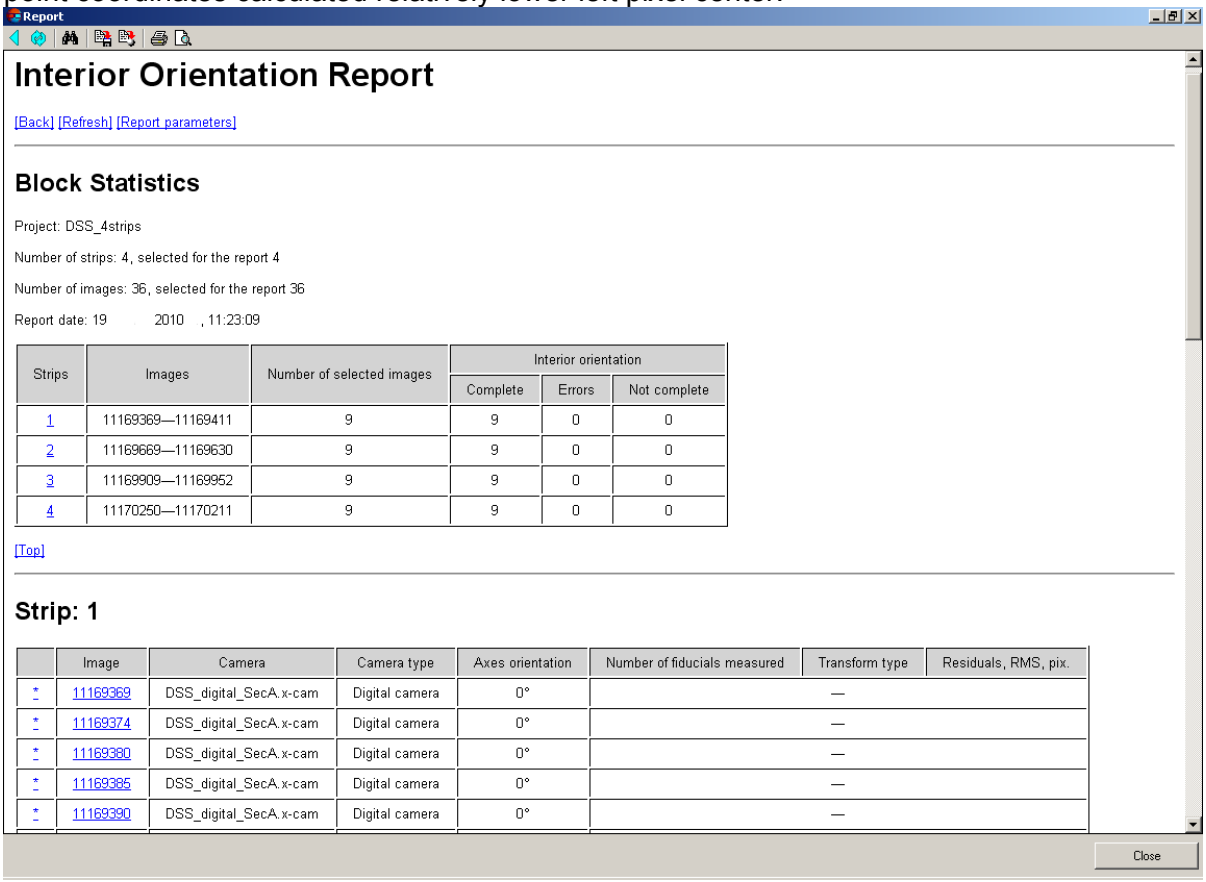
Thus, red color in report always shows the following:

- ***errors on all marks – by selected error (RMS, mean or max) and by residual value specified in report parameters***
- ***errors on each mark – by residual value on maximal error.***

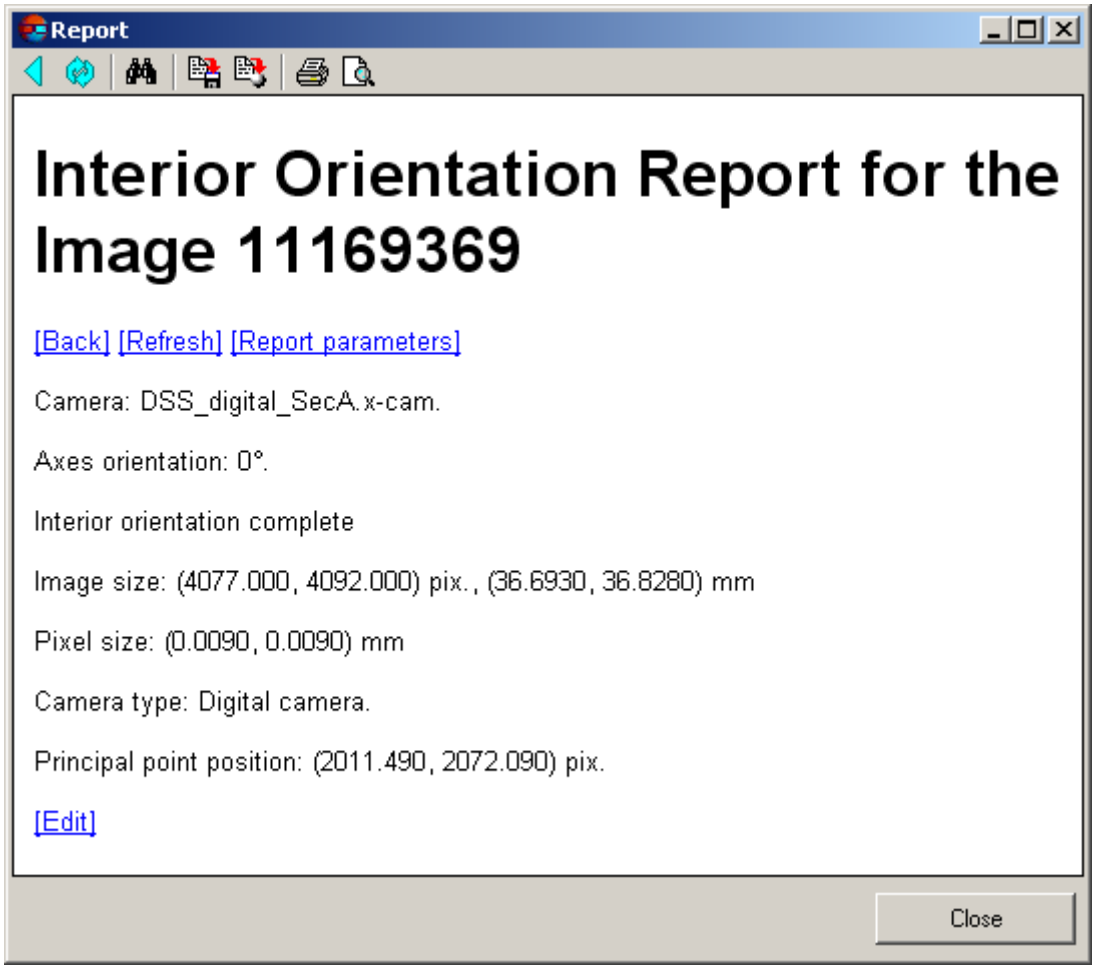
The **[Edit]** link allows to open **Interior orientation** window for the image, where you can re-measure fiducial marks and re-calculate the interior orientation.

Besides, the upper line of the report contains the following links:
[Back] – to return to previous window of a report
[Refresh] – to refresh a report after changing of some its parameters
[Report parameters] – opens window to edit the report parameters

In case of *digital camera*, there are no fiducials on images and the report shows information on whether or not the interior orientation was performed, camera parameters and principal point coordinates calculated relatively lower left pixel center.



Report on interior orientation for digital camera



Report on interior orientation for an image acquired by digital camera

All the report windows (for the whole block or for the image) contain upper toolbar with the following buttons:

– search by word or its part;

– allows to save a report in HTML-file in any folder of file system;

– allows to save a report in HTML-file in active profile resources;

– allows to print a report;

– opens print preview window.

4. Relative orientation and ground control points measurement

To perform aerial triangulation on stereopairs you need to measure a set of ***tie points*** on overlapping images (in addition to ground control points, see the chapter Input and measuring of ground control points). Tie points are used to create models from pairs of adjacent images and to create from these models the whole strip model or the entire block model.

If the block adjustment purpose is only calculating the image exterior orientation parameters, it is not necessary to select tie points on recognizable details of a terrain, because tie points on overlapping images are measured either automatically using the correlation algorithm or stereoscopically by an operator.

If you perform aerial triangulation to measure ground coordinates and heights of some points on images, which afterwards can be used as ground control points in further photogrammetric processing of single images and stereopairs, you should choose the tie points on recognizable terrain details. Such points are referred to as ***targeted*** points below.

Measuring of a tie point means its stereoscopic measuring on both images of a stereo pair at the same time (or on several images which contain the point).

Stereoscopic measuring can be performed manually in Relative orientation module (see the chapter Manual measuring of triangulation points) in three following ways:

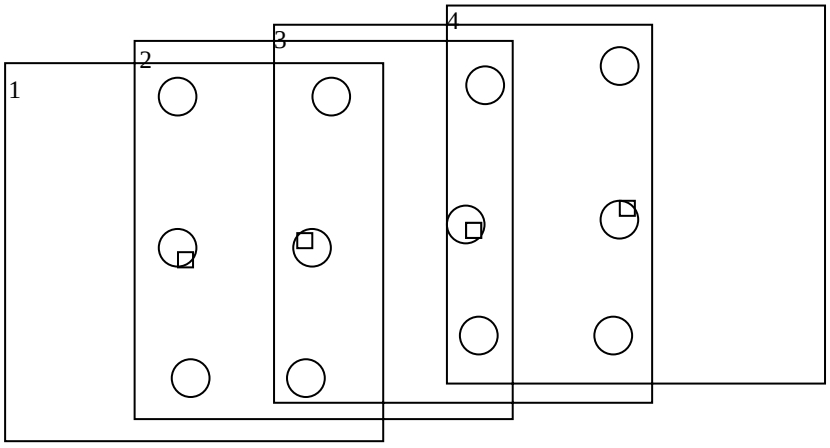
- by manual positioning of the point on each of two images;
- by manual positioning of the point on one image and transferring the marked point to another image with correlator;
- by manual positioning of the point in stereo mode in 3D space.
- by automatic positioning of the point on both images using correlator.

Besides, tie points can be measured in full automatic mode on selected images of a block. See the chapter Automatic tie points measurement.

Note: Ideally, for relative orientation executing you should combine two methods – automatic measurement with "bad" points filtering and manual mode for editing of measurements acquired in automatic mode and adding of new points to obtain satisfactory results.

Automatic mode provides a range of possibilities to perform relative orientation of block images – combinations of a number of parameters for tie points measurement, transfer and filtering using different criteria that can bring satisfactory results even without manual measurements.

When using only manual procedures of relative orientation, the optimal way for block measurement is considering of tie points placement in 6 standard zones for each stereopair (at least 2 points for each zone).

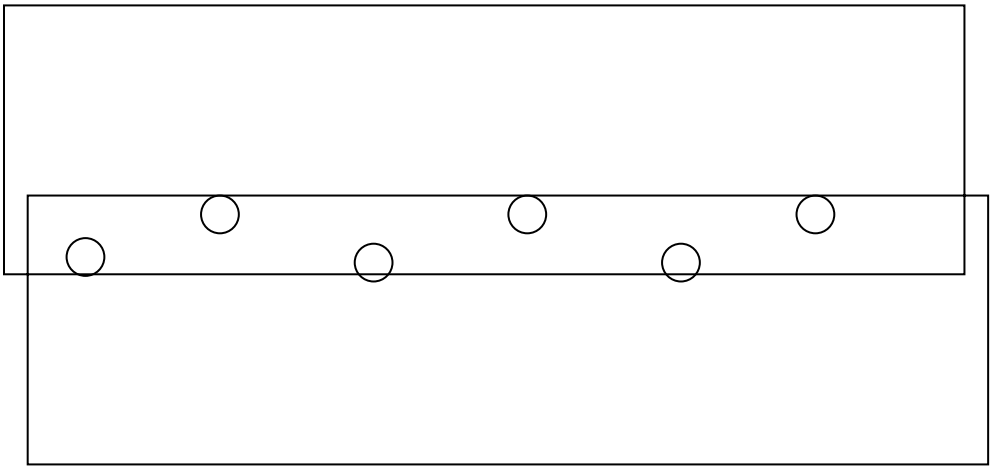


□ image principal point

○ tie points location zones

Recommended zones for measuring tie points inside strips

In order to consolidate images strips into block it is recommended to place inter-strip tie points in inter-strip overlap zones on both sides from midline of overlap area.



Recommended location of tie points in inter-strip overlapping area

Note. If you use block adjustment by independent models method, you should transfer inter-strip tie points to at least one adjacent image in each strip. Otherwise they will be not taken into account when using this type of block adjustment.

4.1 *Orientation menu*

In order to perform data collecting for aerial triangulation procedure use the **Orientation** menu. Its menu items are partly duplicated by the buttons of the main toolbar and the **AT** toolbar.

The **Orientation** menu includes the following items:

- **Manage cameras** – used for input and editing of cameras parameters and assigning them to current project images. See the chapter Cameras management.
- **Interior orientation** – contains menu items used to perform interior orientation procedure. See the chapter Interior orientation menu.
- **QuickTies** – contains menu items used to match the images manually. This data is used to build the block layout. See the chapter Manual matching of images.
- **Tie points list** – allows to open a list containing all measured triangulation points (ground control, control, tie) with measurements data. See the chapter Triangulation points window.
- **GCP points list** – allows to open a list of all measured and non-measured ground control points with their input coordinates (without measurements data). See the chapter Triangulation points window.
- **Delete points measurements** – allows to select triangulation points types for deletion and delete them. See the chapter Point measurements deletion.
- **Clear point catalogue** – allows to delete all triangulation points (GCP, check, and tie) from points catalogue at once.
- **Automatic tie point measurement** – allows to perform tie points measurement in automatic mode. See the chapter Automatic tie points measurement.

- **Report on relative orientation** – used to open a report containing results of relative orientation of images for analysis and removal of measurements errors. See the chapter Relative orientation report.

- **Load triangulation points** – used to load triangulation points to the **2D** window and allows to set up points displaying of the certain type. See also the chapter Displaying points in 2D window.

- **Automatic UAV triangulation** – allows to measure tie points on UAV images in automatic mode.

- **Open selected images for measurement** – allows to open the **Points measurement** module used for points measurement on selected images in manual mode. See the chapter Manual measuring of triangulation points.

- **Open images containing marker** – allows to open the **Points measurement** module used for points measuring in manual mode on images, which contain marker position. See the chapter Manual measuring of triangulation points.

- **Open in-strip stereopair** – allows to open the **Points measurement** module used for points measuring in manual mode on selected stereopair of a strip. See the chapter Manual measuring of triangulation points.

- **Open inter-strip stereopair** – allows to open the **Points measurement** module used for points measuring in manual mode on selected inter-strip stereopair. See the chapter Manual measuring of triangulation points.

- **Exterior orientation data list** – allows to open the **Exterior orientation parameters** window with exterior orientation parameters, which were imported or entered manually. See the chapters Import of exterior orientation data, Exterior orientation data list.

- **Load projection centers as vectors** – allows to transform projection centers data to point vector objects and load them to the **2D** window for analysis.

- **Select subblock** – allows to select the project images to perform the block adjustment.

- **Block adjustment** – allows to set the adjustment parameters, perform block adjustment and display the adjustment results to view and correct them (see **Block adjustment** User Manual).

- **Adjustment in batch mode** – allows to set the adjustment parameters and adjust the block without displaying the adjustment results and to view and correction of residuals (see **Block adjustment** User Manual).

- **Direct georeferencing** – allows to adjust the block from the imported exterior orientation parameters. (see the chapter Import of exterior orientation data).

- **Delete adjustments results** – allows to delete all the adjustment results (see **Block adjustment** User Manual).

- **Import exterior orientation** – allows to import the exterior orientation parameters, if any (see the chapter Import of exterior orientation data).

- **Import orientation from UltraCam metadata** – allows to import orientation data from **UltraCam** metadata. See the chapter Import from UltraCam metadata.

- **Create images georeferencing files** – allows to export the georeferencing data after the preliminary exterior orientation or block adjustment into the ArcInfo World File and MapInfo TAB files format.

- **Import** – contains menu items, that allow to import triangulation points measurements from files of PAT-B and X-Points format, and from **PHOTOMOD 4.x** projects (XPT), as well as to import the flight line file. See the chapter Triangulation points import.

- **Export** – contains menu items, that allow to export triangulation points measurements to files of PAT-B and X-Points format, as well as to export triangulation points to **Geomosaic** program. See the chapter Triangulation points export.

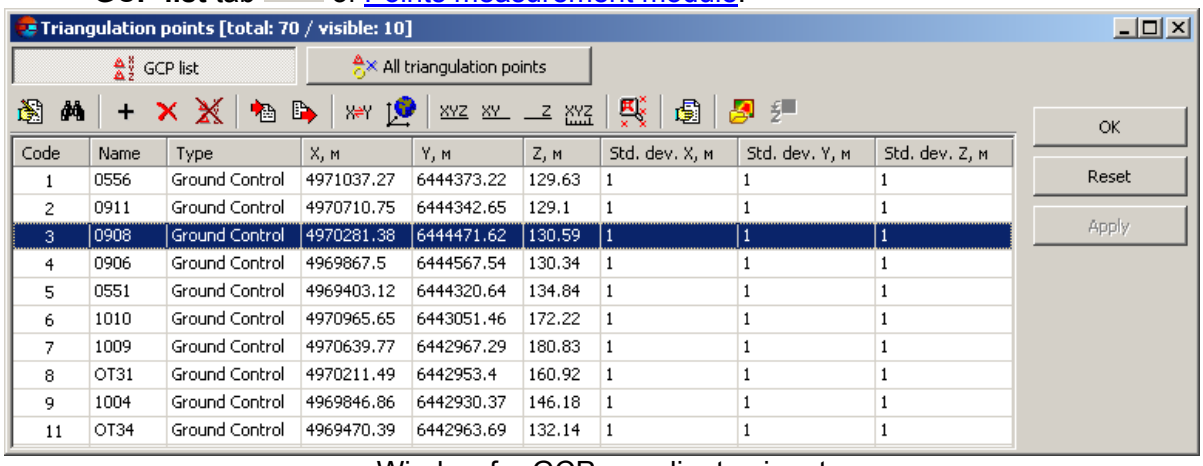
4.2 *Input and measuring of ground control points*

Ground control points are processed in two stages – first you should input GCP coordinates and then recognize and measure them on the block images.

4.2.1 GCP input

You can input ground control points using **GCP list** tab of Triangulation points window, that is opened by:

- menu command **Orientation | GCP points list**
- the button of the main **PHOTOMOD Core** toolbar
- **GCP list** tab of Points measurement module.



Code	Name	Type	X, м	Y, м	Z, м	Std. dev. X, м	Std. dev. Y, м	Std. dev. Z, м
1	0556	Ground Control	4971037.27	6444373.22	129.63	1	1	1
2	0911	Ground Control	4970710.75	6444342.65	129.1	1	1	1
3	0908	Ground Control	4970281.38	6444471.62	130.59	1	1	1
4	0906	Ground Control	4969867.5	6444567.54	130.34	1	1	1
5	0551	Ground Control	4969403.12	6444320.64	134.84	1	1	1
6	1010	Ground Control	4970965.65	6443051.46	172.22	1	1	1
7	1009	Ground Control	4970639.77	6442967.29	180.83	1	1	1
8	OT31	Ground Control	4970211.49	6442953.4	160.92	1	1	1
9	1004	Ground Control	4969846.86	6442930.37	146.18	1	1	1
11	OT34	Ground Control	4969470.39	6442963.69	132.14	1	1	1

Window for GCP coordinates input

To add a new point to the list, click the icon. For each point enter a point name (**Name** field), its X, Y, Z coordinates (**X**, **Y**, **Z** fields) and accuracy values for each coordinate (**RMS X**, **RMS Y**, **RMS Z** fields). The **Type** field is used to set the type for a point – **Ground control** (default type) or **Check**. Control points are not used in block adjustment, but are used to check the adjustment accuracy (see also **Block adjustment** User Guide).

PHOTOMOD system works with plain-height (X,Y,Z), plain (X,Y) and height (Z) point's coordinates. During input of Z or XY points in field with no coordinates, "0" value appears by default. Use the buttons , to exclude appropriate coordinates when input plain or height points (the appropriate field becomes empty). The button is used to input of all three coordinates.
You can edit the coordinates, accuracies and point's type by clicking the appropriate field.

Beside manual input of coordinates values you can use coordinates import from text file (see the chapter Import of GCP list).
After coordinate points input you can proceed to their measurement on images stage (see the chapter GCP measurement).

The toolbar of GCP catalog window is used for the following operations:

– enable editing mode for GCP

– GCP search by its name

– new point adding

– selected points deletion (editing mode should be disabled). Deletes points selected in the list along with all their measurements.

– deletion of all input GCP

– import of GCP list from text file (see the chapter Import of GCP list)

– export of GCP list to text file (see the chapter Export of GCP list)

– swap X and Y coordinates for selected or for all points

– recalculate coordinate system for selected or for all points

– use all three coordinates for XYZ points (by default). It is used to restore excluded coordinates values, if one of two types were applied to a point – Z or XY point

– is used for a planimetric points, it excludes Z coordinate (the Z coordinate value is shown in grey color). The field is editable. After editing of the excluded Z value it is automatically turned on (i.e. it will be involved into adjustment).

– is used for a vertical point, it excludes X and Y coordinates (the coordinates values are shown in the appropriate fields in grey color). The fields are editable. After editing of the excluded X and Y values they are automatically turned on (i.e. they will be involved into adjustment).

– opens the **Set control points coordinates accuracy** window used to associate accuracy values (RMS) by XY or Z coordinate to all or to selected GCP

– find/measure selected point. The button click is duplicated by double click on selected point. Shows GC point in Points measurement module on images where it is measured, or shows the images where it can be measured (with marker located in the place of supposed measuring). If the point is not measured, the system shows its appropriate images after measuring of first 2-3 GC points or in case if preliminary orientation was performed in geodetic coordinate system (by projection centers, for instance).

– opens relative orientation report (see also the chapter Relative orientation report).

– allows to open DEM used for extraction of Z-coordinate for GCP selected in the list (if they are not available, for instance). Name of opened DEM and its path appears in status line. The button for DEM closing is in the same place.

– allows to obtain Z-coordinates from DEM for selected points

Note. For adjustment of airborne images block you should have projection centers coordinates or at least 3 ground control points. Every point should be measured on at least 2 images on stages of strip ties and images tie points measurements. About number of GCP for adjustment of scanner images blocks see the chapter Number of GCP necessary for space images processing in PHOTOMOD.

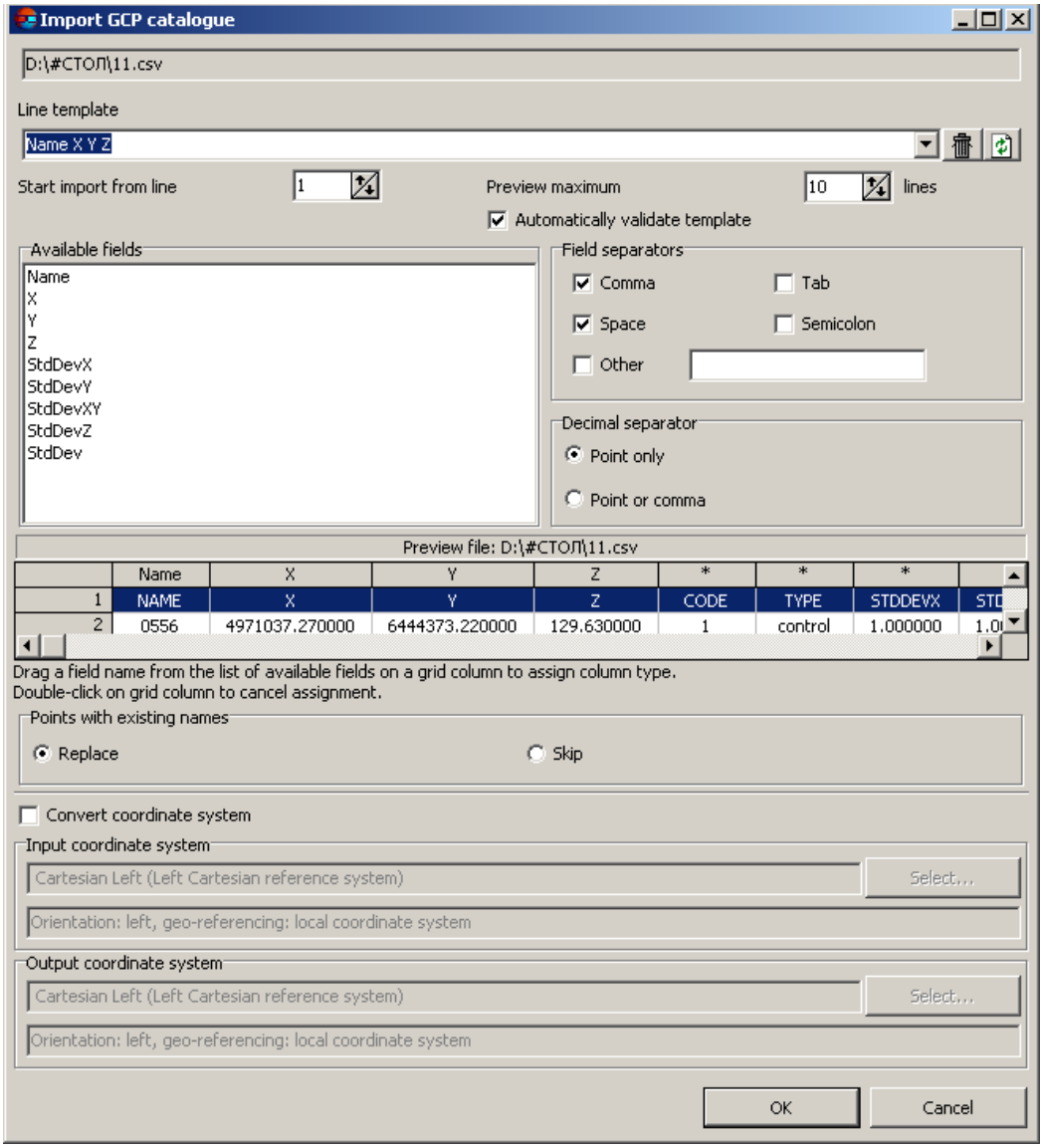
Note. GCP coordinates are given in the coordinate system selected during project creation in PHOTOMOD Core (see Project creation User Guide).

4.2.1.1 *Import of GCP list*

Text file suitable for GCP import to **PHOTOMOD** system should contain strings like following:

NAME,X,Y,Z,STDDEVX,STDDEVY,STDDEVZ
0556,4971037.270000,6444373.220000,129.630000,0.10000, 0.1000000, 0.1000000
0911,4970710.750000,6444342.650000,129.100000, 0.1000000, 0.1000000, 0.1000000
0908,4970281.380000,6444471.620000,130.590000, 0.1000000, 0.1000000, 0.1000000
0906,4969867.500000,6444567.540000,*, 0.1000000, 0.1000000, 0.1000000
where:
name – a name of a GCP,
X, **Y**, **Z** – ground coordinates of this point,
STDDEVX, STDDEVY,STDDEVZ – accuracy of coordinates measuring (RMS) along X, Y, Z axes.
Plane position accuracy data (**STDDEVXY** field) or accuracy along of each axes - **STDDEV** can be imported, if they are set in current fields.
Data of other fields are not usable for import.

Push the button on the GCP list tab of the **Triangulation points** window to import GCP's coordinate catalogue. Select the GCP catalogue text file. Push the **OK** button. The **Import GCP catalogue** window opens.



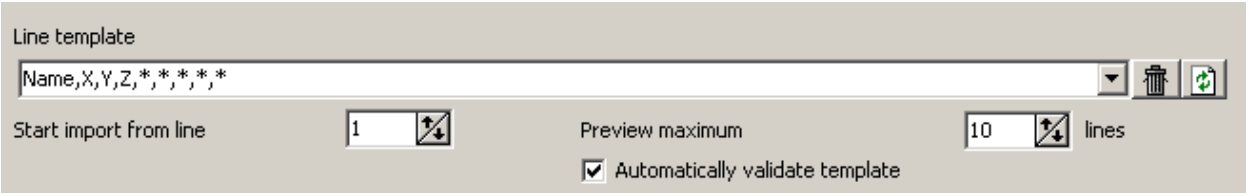
Import of GCP's

The main application of the **Import GCP catalogue** window consist in setting of an imported template file to detect the type of data in the columns of the file and successful imported.

Data of the selected file are displayed in the **Preview file** list. Table columns types are automatically set according to the template (in the **Line template** field), was used during the last file importing with GCP catalogue.

Note: The symbol * is used to mark the columns containing data not to be imported.

To display the current template which corresponds to the table data push the button (**Validate template**). The column's types and number will be defined *only for the rows displayed in the table*. The template field number will be equal to the maximum columns number in the table rows displayed.



Current template for table data

To set the current template performs one of the following actions:

- Using mouse, drag the field name from the **Available fields** list onto the table column to define the column type. The template in the **Line template** input field will be automatically changed. Double-click on the table columns cancels the field selection.

- Change the template manually in the input field Line template. The table column's types are changed automatically.

The **Automatically validate template** checkbox provides automatic selection of the current template on pressing the **Next** button. So it is enough to define the table's to be imported columns types, to set the **Automatically validate template** checkbox and push the Next button. If the file contains rows with different columns number, unselect the **Automatically validate template** checkbox and set the template manually in the **Line template** input field.

To define the file rows number to display in the table set it in the **Preview maximum lines** input field. To define the row number to start the data import set it's number in the **Start import from line** filed.

Note: the current template (on pressing the ***button) will correspond to those rows only which are displayed in the table.***

In the appropriate window sections set the file columns delimiter's type (**Comma**, **Space**, **Tab**, **Semicolon** or **Other** delimiters) and decimal delimiter for the coordinates values in the file (**Point only**, **Point or comma**).

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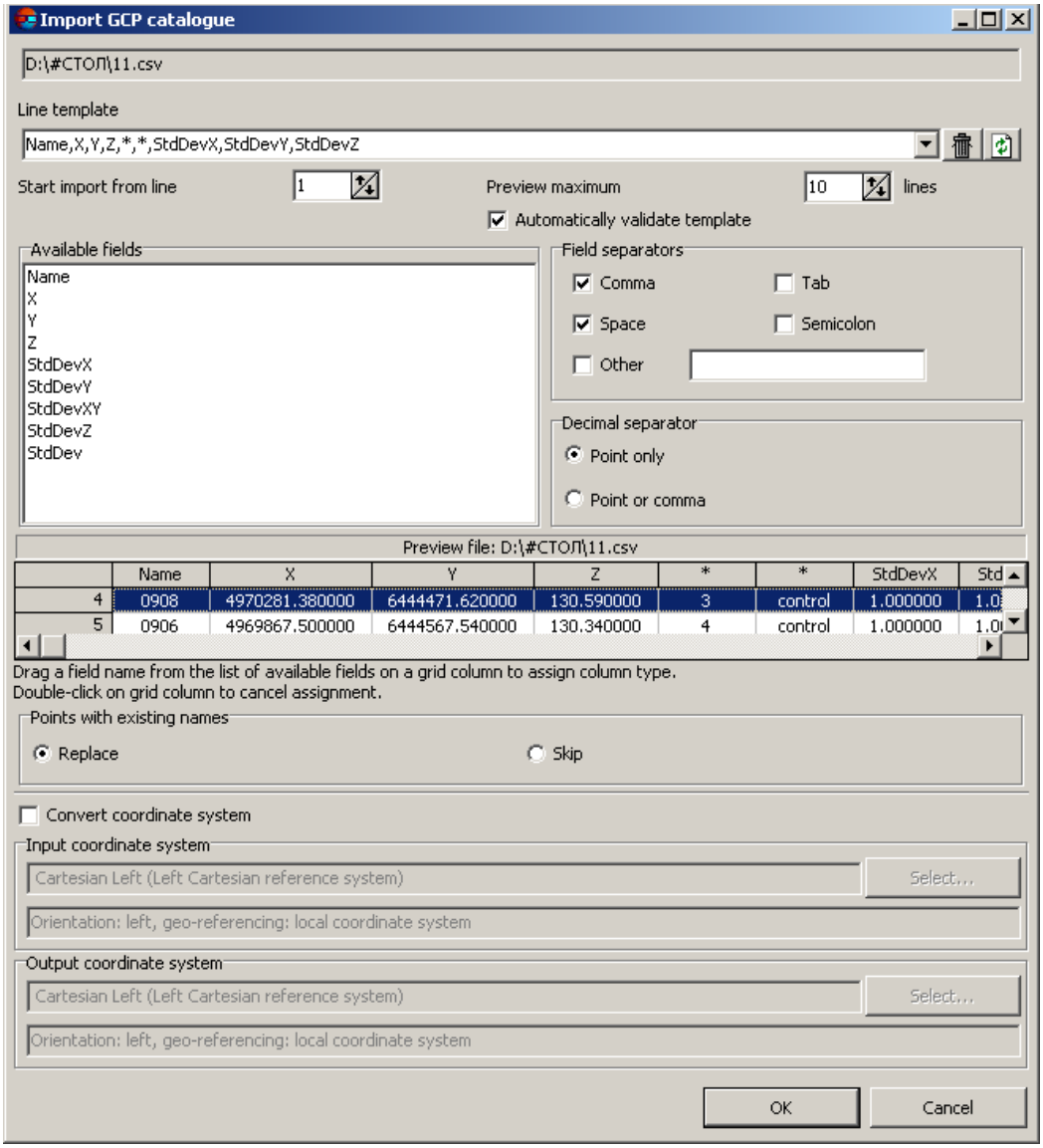


Template settings for imported file

The text file (shown in fig. above) contains 9 columns from which only 7 (Name, X, Y, Z, StdDevX, StdDevY, StdDevZ) are suitable for import; CODE, TYPE columns type are excluded from the import and marked by "*" symbol in the template. Data import will begin from the second row, because the first row represents the fields header. The field separator is a comma, the decimal separator - point.

The button is used to return to template by default (Name X Y Z).

After setting template for the imported file, define the action in case of identical names of the imported GCP's and names of existing points in the list on the GCP's list tab of Triangulation points window.

Recalculate the coordinate system if it necessary. To do this, specify the source and the output coordinate system in the corresponding sections of the window. Push the OK button.

The imported data will be added to the end of the GCP's list on the GCP's list tab of the **Triangulation points** window.

4.2.1.1 *Export of GCP list*

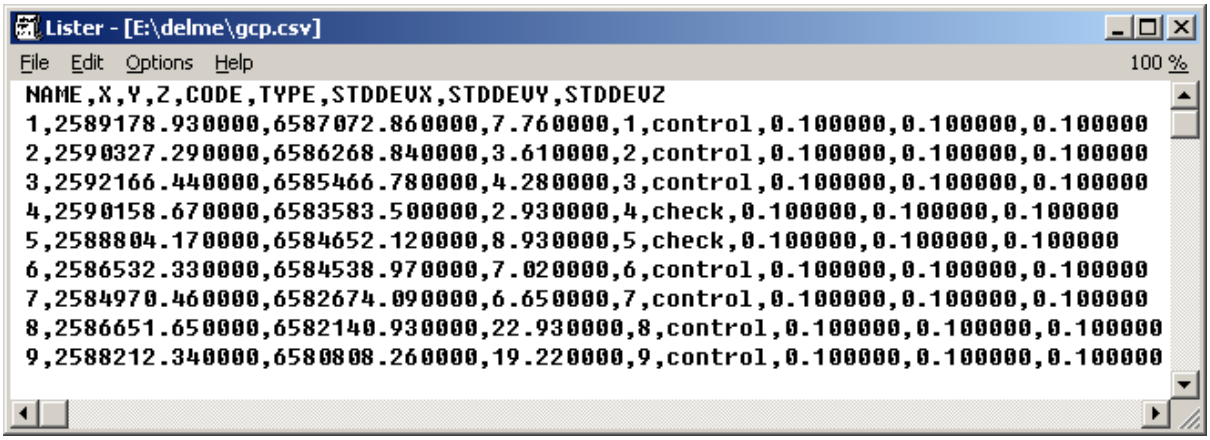
Push the button on the GCP's list tab of the **Triangulation points** window to export the GCP's catalogue. **Export GCP catalogue** window opens for specifying file name of the csv or txt formats.
GC points will be exported to text file of the following format:

NAME, X, Y, Z, CODE, TYPE, STDDEVX, STDDEVY, STDDEVZ

where **NAME** – GCP name,

X, Y, Z – coordinates values ("*****" is used for missing coordinate values),
CODE – point's code,
TYPE – GC point's type (control – GCP, check – check point),
STDDEVX, STDDEVY, STDDEVZ – RMS errors.

Comma is used as fields' delimiter, and full stop as a decimal separator. The first line contains fields' headings.



Example of GCP catalogue export to text file

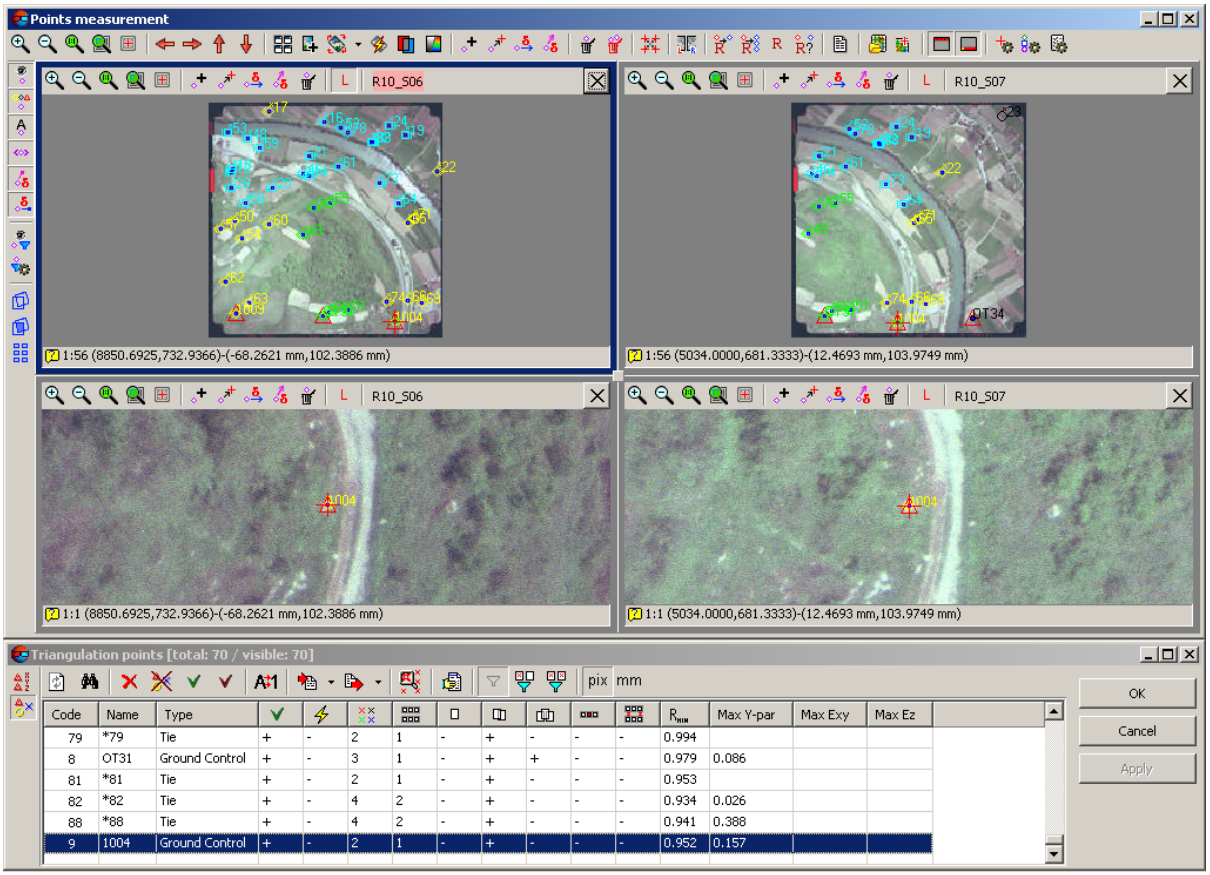
4.2.2 GCP measurement

After GCPs coordinates input you should recognize and measure ground control points on images. GCP measurement is performed in Points measurement module.

For measurement and editing of GCP in **Points measurement** module, it is recommended to use the **All triangulation points** tab, since the list shows measurement data, you can sort it to find unmeasured points, etc. See also the chapter Triangulation points window.

Selecting of ground control point for measurement

Select GC point in the list of **Triangulation points** window and click the button **Show point on images** (duplicated by double click on selected point). At that if the orientation has been already performed in geodetic coordinate system (e.g. by projection centers and after measuring of 2-3 ground control points), all images which may contain selected point are opened. The marker on the images is located in place of supposed measurement, i.e. the system performs automatic marker positioning to current point neighborhood.
Otherwise (if there is no orientation performed), select and open needed images for new GC point measurement by clicking the button **Add images** in the **Points measurement** window. See also a description of Main window of Points measurement module.



GCP measurement without correlator

GCP measurement

General workflow of GCP measurement in **Points measurement** module is the following:

- Select GC point you want to measure in the list.
- Select images containing this point in the **Points measurement** window (if the point is located in overlap zone).
- Measure the point by one of the following ways:
  – *measurement without correlator*. Use it if the point is located on the ground and is well-recognizable on all images. Show by the marker its precise location on images. Push the button **Add or move point measurements to marker positions on all images** in main toolbar of the **Points measurement** window.
  – *measurement and transfer using correlator*. Use it if the point is not well-recognizable on all images. In this case measure the point on one image using the button **Move/add measurement into marker position** in toolbar of image window (see also the chapter Windows of opened images). Specify this image as left – . Then transfer the point measured on the left image on other images using correlator by clicking the buttons or on the main toolbar of the **Points measurement** window, keeping under control correlation coefficient (recommended coefficient value is 0.90 – 0.95).
  – *measurement in stereo mode*. Use it if the point is located above the ground (on high object) and is not shown on all images. See the chapter Points measurement in stereomode.
- When the point has been measured, information about its measurement appears in the list on the **All triangulation points** tab in **Triangulation points** window.

GC point transfer

- Select measured GC point in the list (by double click)

- Show by the marker a new location for the selected GC point
- Transfer the point to a new location using the button **Add or move point measurements to marker positions on all images**.

GC point deletion

- *GC point measurement deletion.* After deleting GC point measurement from images using the button , only the point measurement is removed, the point with its coordinates remains in the list.
- *Entire GC point deletion.* When deleting GC point measurement from the list using the button , the point is removed entirely from the system (measurement is removed from images, the point is removed from the list along with its coordinates).

Search for a point in the list

To search for a point in the list click the button . In the opened **Find** window input GC point name (number) into **Find** field, and after that the appropriate entry will be selected in the points list.

Moreover, you can acquire GC points coordinates from scanned and georeferenced raster map, vector map or DEM for the same territory, which was a subject of airborne or space survey. More details about raster map georeference see in the chapter Raster map georeference, about obtaining of GCP coordinates from raster and vector maps – in the chapter Adding points from a raster map and Adding points from a vector map.

Measuring control point on map

The program provides the function for obtaining the coordinate of control points from the georeferenced base (for example, raster and vector map or DEM, covering the same area as the project images) and measuring on the project images. See chapter Measuring control point on map.

4.2.3 Measuring control point on map

If external data, covering the same area as project images, is present then it is possible to use it as base for obtaining the control points coordinates and measuring it on the project images.

The general workflow for measuring control point is following:

1. Loading of georeferenced base (*map*).
2. Search selected terrain point of *map* on the project images.
3. Adding/measuring of the control point on the project images.
4. Editing of control point.

4.2.3.1 *Preparation and loading of georeferenced data*

Do the following beforehand to use a georeferenced base image (map):

1. Prepare the input data. In the Windows file system, define the folder for location the raster map - raster file format (TIFF, JPEG, BMP, IMG, PNG, NTF, GIF, PIX, JP2, DEM) and georeferencing file with the same name (see also chapter Georeferencing raster map). Pre-import the external vector data and DEMs into the files of the **PHOTOMOD** internal format (x-data and x-dem, respectively) and save them in the

folder of active profile. See the description of import vector data and DEM in the **Project processing** User Manual.

2. Open the project.
3. Open the **AT** module.
4. Push the button in the main toolbar of the **Aerial triangulation** module. The Map window opens. All loaded data into the **2D** window are displayed in working area of the **Map** window. Push the button to display the layer list and managing layer.
5. Load the georeferenced base (*map*):

Loading of georeferenced data	Actions
Loading of raster map	Push the **Load georeferenced images** button. The **Loading images** window opens. Select the raster map file and push the **Open** button. The **Load georeferenced images** window opens. If necessary choose coordinate system transformation corresponding to the project coordinate system. If the raster map contains background on the edges, then select transparent background for such areas. Push the OK button. The new raster layer appears in the layer manager and the loaded raster map displays in the working area of the **Map** window.
Loading of vectors	Push the **Load vectors** button. The **Open** window opens. Select the vector file in the resources of active profile, convert, if necessary, the coordinate system and push the **Open** button. The new vector layer appears in the layer manager and the loaded vector data displays in the working area of the **Map** window.
Loading of DEM	Push the **Load DEM** button. The **Open** window opens. Select the DEM file in the resources of active profile and push the **Open** button. The new DEM layer appears in the layer manager and the loaded DEM displays in the working area of the **Map** window.
Loading of web-map	Push the **Load web-map** button. The **Load web-map** window opens. Select the WMS data source in the **Source** list. Define the working area to load web-map. In the **Reproject** panel define the coordinate system for loaded web-map: Auto (reproject into project working coordinate system), None (use coordinate system of the web-service) or Reproject into coordinate system.

4.2.3.2 *Searching corresponding GCPs on images*

Before the adding / measuring of GCPs, select the visual ground sign on the *map* and set the marker in this place, and then define the corresponding terrain point on the project images. Searching of the corresponding terrain point on the images is performed as follows:

The presence of measured GCPs in the project and / or the presence and use of the exterior orientation data	Actions
The project lacks for measured GCP and Exterior orientation data	In the AT module, select and open the project images containing the selected terrain point using the button. Next, manually define this terrain point on the opened images of the project using a marker.
The project already has the measured GCP (at least 2 points) and / or the external orientation data were used for block layout creation	Use the synchronization tools to search the terrain point on the project images: • Push the **Synchronize marker** button in the **Map** window to automatic search the corresponding terrain point

	on the images, *opened* in the **AT** module. If necessary, specify the location of the marker on the images. • Push the **Synchronize marker (with images selection)** button in the **Map** window to search the corresponding terrain point on the all project images. All images, in which the corresponding point is found, are automatically opened in the **AT** module. If necessary, specify the marker location on the images. **Note:** Also provides for the reverse synchronization - searching the terrain point of image on the map. To do this, set the marker on the some terrain point on the image (in the active window); next, push the **Find on map** button of the main window in the **AT** module.

4.2.3.3 *Adding to list and measuring GCP on project images*

Add/measure the GCP after the selecting of the terrain point. The program provides the following options for adding/measuring GC point:

- Adding GCP without correlation.
- Adding GCP with correlation. The presence of the measured points in the project or the exterior orientation data with building of the block layout from this data is necessary for using the correlation for adding GCP. In addition, an option is provided to use DEM for obtaining the value of Z-coordinates of the point.

Adding GCP without correlation

Perform the following actions for quick adding of GCP without correlator:

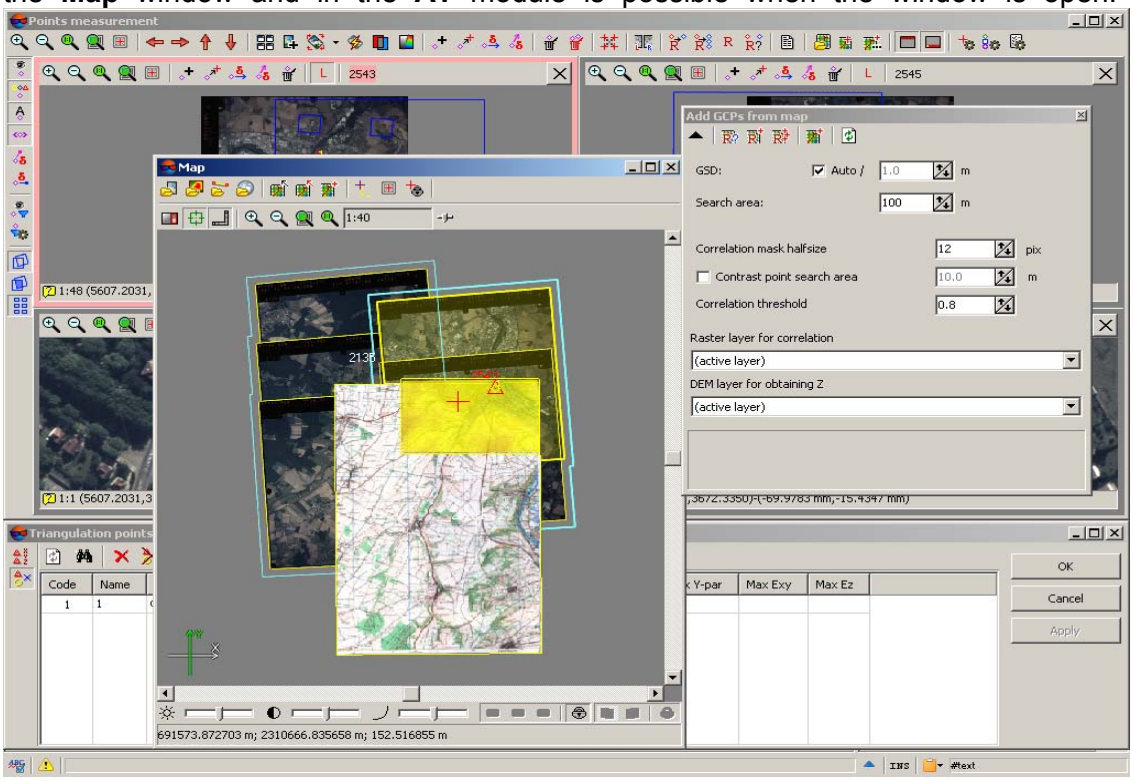
1. Make active the *Maps* layer.
2. Set the correspondence between the terrain points on the map and on the images using the marker (see chapter **Searching of the corresponding GCPs on the images**).
3. Push the button in the **Map** window. New GC point displays on the images and appears in the in the triangulation points list of the **AT** module. If necessary, edit the coordinate values or change the type of point (ground control point, check point) on the GCP list tab (see chapter Triangulation points window).

Adding GCP with correlation

Perform the following actions to add the GCP using correlator:

1. Make active the layer of raster map. If the DEM is available, load it into the **Map** window.
2. Select the terrain point, using the marker, on the raster map. Push the **Synchronize marker (with images selection)** button in the **Map** window for automatic opening of the project images, containing this terrain point, in the **AT** module.
3. Push the **Open tool panel for adding GCPs from map** button in the **Map** window. The **Add GCPs from map** window opens. The window is modal, i.e. work in

the **Map** window and in the **AT** module is possible when the window is open.



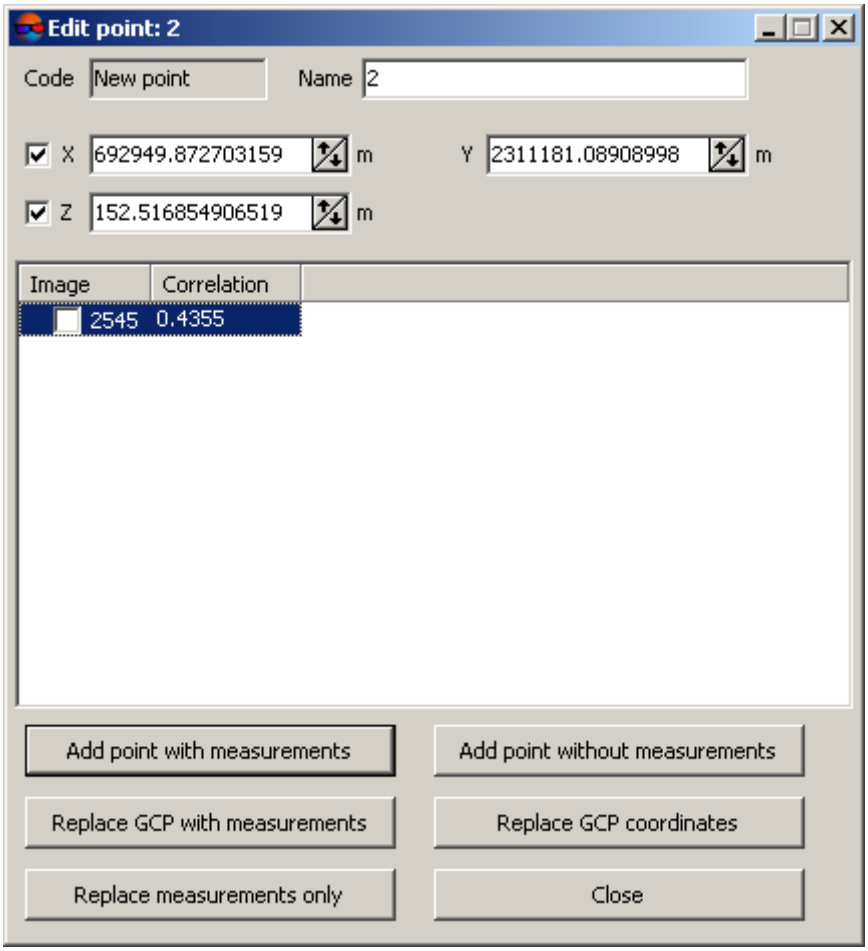
4. Specify the active layer of the raster map in the **Raster layer for correlation** field. Specify the DEM layer (if is available) in the **DEM layer for obtaining Z** field. If necessary, refresh the layer list using the button.
5. Edit the correlator parameters.

Correlator parameters	Purpose
GCD	Set the **Auto** check box for automatic definition of GCD or specify the GCDs value manually.
Search area	Specify the search area of the corresponding point on the image in meters (100 by default)
Correlation mask halfsize	Specify the size of correlation mask on the X and Y axes in pixels (12 by default).
Contrast point search area	Set the check box and define the value of search area in meters (10 by default), in which the searching of maximum contrast point will be performed. The parameter can be useful for images with the increased percentage of the continuous-tone areas. It is recommended to set the 0 value during the measuring of points in areas of low contrast (for example, when the maximum contrast corresponds to the forest vegetation; the chances are high that the correlation will be with errors within this area).
Correlation threshold	Determine the minimum acceptable value of correlation coefficient for measuring of points (0.8 by default) based on the images quality. The point with the correlation threshold, below the set value, will not be considered when adding (The «Bad point» message is shown).

6. Add the GCP using correlator. The window provides the following tools to do this:

Button	Purpose
Correlate and move marker	This feature allows searching the corresponding point on the active images using the correlator and moving the marker to the obtained point. If the correlation will be satisfactory, the marker falls into the obtained point. Otherwise, the «Bad point» message is shown. Select another terrain point on raster map.
Add point with correlation on the active image	This feature is used to adding / measuring of GCP on the image in the active window. The search of corresponding point is performed when the button is pushed. If the correlation will be satisfactory, the marker falls into the obtained point and the **Edit point** window (see description below). Otherwise, the «Bad point» message is shown. Select another terrain point on raster map.
Add point with correlation on all images	This feature is used to adding / measuring of GCP on all opened images in the **AT** module. The search of corresponding point is performed on all images when the button is pushed. If the correlation will be satisfactory, the marker falls into the obtained point and the **Edit point** window (see description below). Otherwise, the «Bad point» message is shown. Select another terrain point on raster map.
Add point without correlation	This feature allows quick adding the new GCP without correlator into the location of marker.

The **Edit point** window is used to view/edit coordinates of selected terrain point, as well as estimate the correlation coefficient and select such images, on which the new point will be measured.



Enter the name of new GCP in the **Name** entry field. Define coordinates, which will be added. The value of Z-coordinate is displayed if the DEM has been used. The list below, estimate the correlation coefficient and select the images, on which the new GCP will be measured. The following options are provided for adding / measuring of GCP:

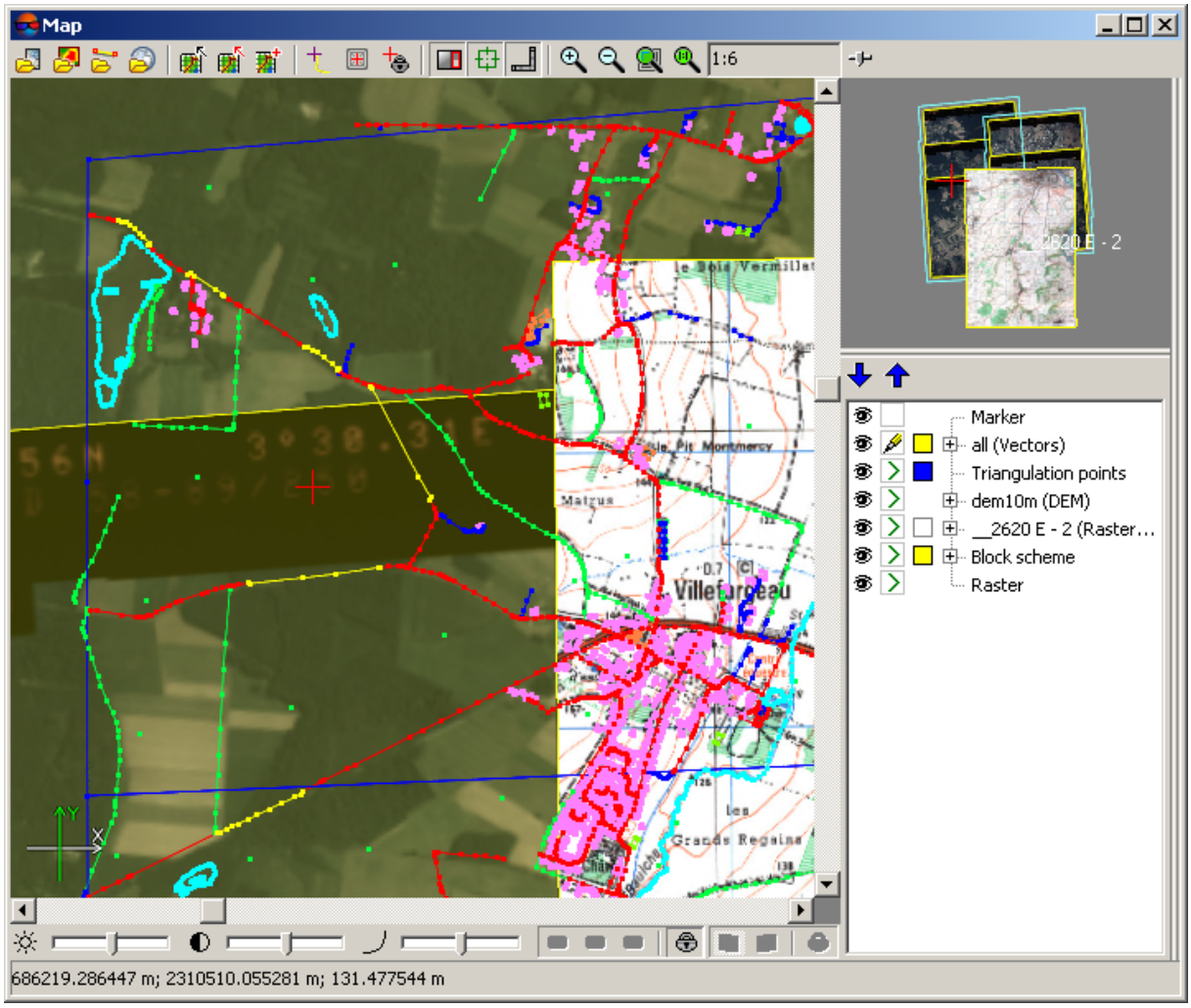
Button	Purpose
Add point with measurements	This button allows adding new GCP with coordinates in the Triangulation point list and measuring it on the selected images.
Add point without measurements	This button allows adding new GCP with coordinates in the triangulation point list without measurement on the selected images.
Replace GCP with measurements	This button allows replacing coordinates of selected point in the triangulation points list and re-measuring it on the images.
Replace GCP coordinates	This button allows replacing only coordinates of selected point in the triangulation point list without editing of measurement.
Replace measurements only	This button allows re-measuring point, selected in the triangulation point list, on the images without editing of coordinates.

7. If necessary, edit the GCP in the **AT** module after its adding/measuring.

4.2.3.4 *Map window*

Main purpose of the **Map** window is the georeferenced data loading (raster and vector maps, DEM) to use for adding and measuring of GCP on the project images.

The Map window opens using the button of main toolbar of AT module.



Map window

All data, opened in the **2D** window, are displayed in the working area of **Map** window. The **Map** and **2D** windows are fully synchronized by content. On the right is the manager layer window for managing these data and a navigation window for quickly moving to necessary data.

The top part of window contains the following tools:

- – Loading of raster map – Window allows to select raster format file in the Windows file system (TIFF, JPEG, BMP, IMG, PNG, NTF, GIF, PIX, JP2, DEM), see chapter Preparation and loading of georeferenced data.
- – Loading of DEM – Window allows to select the DEM in the resources of active profile for obtaining Z-coordinate from it (see chapter Preparation and loading of georeferenced data).
- – Loading of vectors – Window allows to select the vector file in the resources of active profile (see chapter Preparation and loading of georeferenced data).
- – Loading of web-map – Window allows to select source of geospatial data of WMS standard and load web-map, covering selected area (see chapter Preparation and loading of georeferenced data).
- – Search the marker position in the windows of opened images. Searching of area, specified on map using marker, on the images in the opened windows of **AT** module. The use of the tool to search points is possible if the projects images already

have measured GCPs (at least 2) or block layout is built by exterior orientation data (see chapter Searching of the corresponding GCPs on the images).

- – Search on the project images – the searching of terrain point on all images is performed. The use of the tool to search points is possible if the projects images already have measured GCPs (at least 2) or block layout is built by exterior orientation data (see chapter Searching of the corresponding GCPs on the images).
- – Add GCP without correlation – allows quick adding and measuring GCP on the selected images (i.e. allows transferring GCP with coordinates from map to the marker position on the selected images). The added point displays on the images and appears in the list of triangulation points of the **AT** module. If necessary, edit the added point. For example, change the name or type (GCP, check point) (see chapter Adding to list and measuring of GCP on the project images).
- – Panel of adding GCP – allows to add and measure GCPs. Window allows using the correlation algorithm for searching of corresponding point on the images, as well as the DEM for obtaining Z-coordinate (see chapter Adding to list and measuring of GCP on the project images).
- – marker mode == mouse (duplicated by the **F4** button).
- – center on marker (duplicated by the **F7** button) – image in the Map window is moved in such a way that the marker falls in the center of the window.
- – fixed marker mode (duplicated by the **F6** button) – in this case, the marker is always in the middle of the screen and moving the mouse results in a corresponding movement of the image.
- – service panels – allows to open/close the service panels to the right of the working area (the layer manager and the navigation window).
- – navigation window – allows to open/close the navigation window.
- – scrollbars – allows to show/hide the scrollbars.
- – zoom in.
- – zoom out.
- – zoom to fit (duplicated by the **Alt-Enter** shortcut)
- – show in the 1:1 scale (duplicated by the **Alt-1** shortcut)
-

– field that displays the scale of image in the window. The scale can be set using the slider.

Moving the image in the **Map** window is performed using the mouse with the pressed **Alt** button (panning mode).

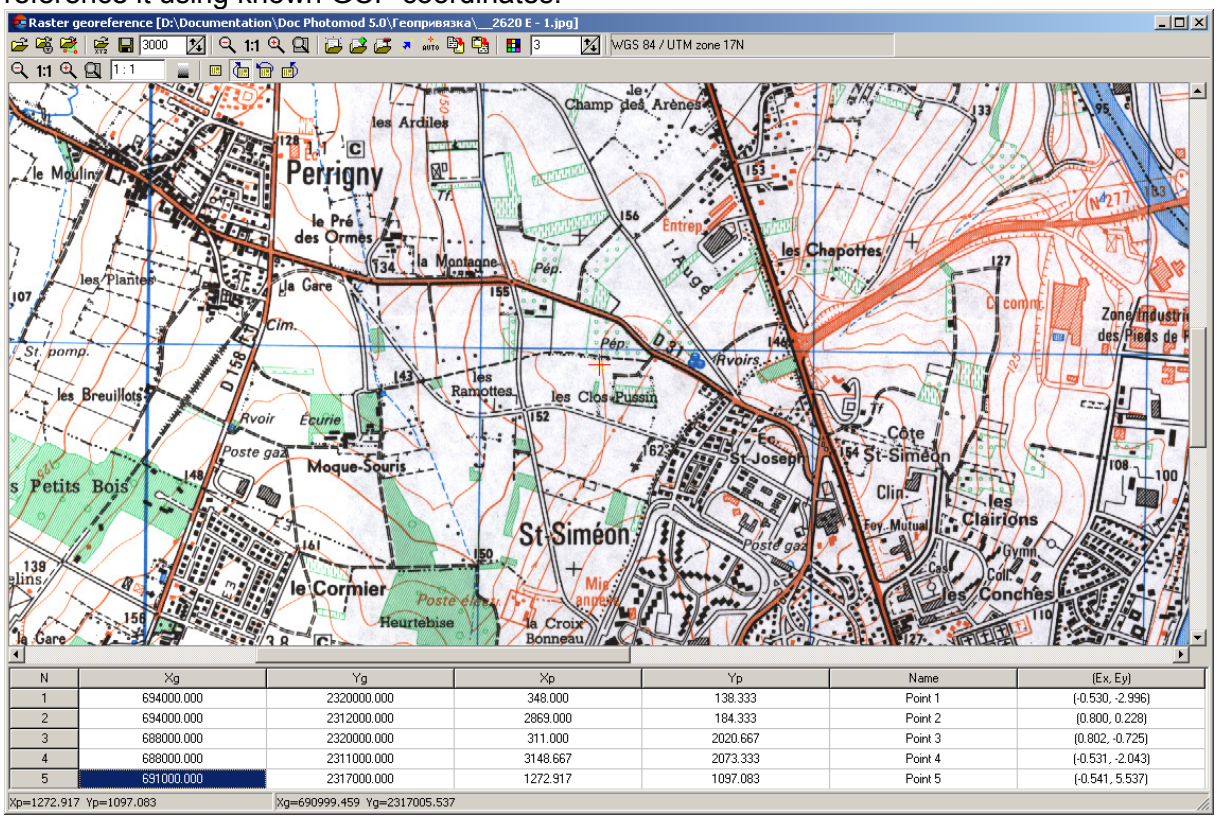
The bottom part of the **Map** window contains the sliders for adjusting brightness, contrast and gamma-correction of images.

The status bar at the bottom of the window displays the coordinates of the marker on the georeferenced map.

4.2.3.5 *Raster map georeference*

For ground control point's coordinates acquisition it is helpful to use scanned and georeferenced topographic map for the same terrain, which was surveyed for acquisition of aerial and space images processed in **PHOTOMOD** project. Scanned map could be georeferenced using ground control points coordinates in **PHOTOMOD Core**.

For raster image georeference use menu command **Service | Image georeferencing**, that opens the window **Raster georeference**. This window allows to open raster map and reference it using known GCP coordinates.



N	Xg	Yg	Xp	Yp	Name	(Ex, Ey)
1	694000.000	2320000.000	348.000	138.333	Point 1	(-0.530, -2.996)
2	694000.000	2312000.000	2869.000	184.333	Point 2	(0.800, 0.228)
3	688000.000	2320000.000	311.000	2020.667	Point 3	(0.802, -0.725)
4	688000.000	2311000.000	3148.667	2073.333	Point 4	(-0.531, -2.043)
5	691000.000	2317000.000	1272.917	1097.083	Point 5	(-0.541, 5.537)

Map georeferencing window

If the file with scanned topographic map is stored in the same folder as georeference file in MapInfo TAB format (georeference file name should be the same as map file name), the list of georeference points and their coordinates is opened in **Raster georeference** window. In this list Xg, Yg – geodetic coordinates, Xp, Yp – pixel coordinates, Name – point name.

To visualize a point in raster window (to place marker in point's pixel coordinates) click the cell in the **Name** column and in the raw of the point's number in the table.

Upper menu buttons are intended for the following operations:

- load raster map – opens dialogue of raster file selection in main raster formats (duplicated by **Ctrl-O** shortcut)

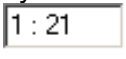
- load reference map – opens dialogue for selection of raster file with map (in main raster formats)

- load vector map – opens dialogue of vector file selection in DXF, DGN or Shape format.

- load XYZ points from file – opens dialogue of GCP coordinates file selection (in TXT format) and opens it as a table below the map window. Point's coordinates could be loaded replacing opened coordinates or in addition to them, after an appropriate warning.

- save – saves georeference file in MapInfo TAB format, at that file name is the same as map file name but with TAB extension.

- zoom management, duplicated by hot keys usual for **PHOTOMOD** system - **/**, **Alt-1**, *****, **Alt-Enter** respectively

 - shows zoom scale in raster map window

- map displaying in grayscale or color mode

For more convenient work the map could be rotated in following ways: - without rotation, - turn at 90 degrees, - turn at 180 degrees and - turn at 270 degrees. At that raster file is not changed and the rotation is executed “on the fly“.

- clear – deletes all points (list cleanup)

- add point – measures new point coordinates on the map and adds them to the end of list. At that marker pixel coordinates are assigned to point and 0 value is assigned to geodetic coordinates (you can enter them manually to appropriate cell by replacing text selected by mouse in this cell)

- delete point – deletes a point selected in the list, duplicated by hot keys **Ctrl-Del**

- re-measure – replaces pixel coordinates of selected point. At that current pixel coordinates of marker are assigned to the point and saved to the list

- auto-place – places marker to coordinates of point, selected in the list

- copy coordinates to clipboard – copies coordinates of selected point to clipboard. Coordinates are in the following format "Xp Yp Xg Yg"

- paste coordinates from clipboard – pastes selected point coordinates from the clipboard in the following possible formats: "Xg Yg", "Xg Yg Zg", "Xp Yp Xg Yg", "Xp Yp Zp Xg Yg Zg", where Zp equals 0.

- select color – opens standard OS Windows palette to choose GC point’s symbol color on the map.

For map georeferencing you should recognize points with known geodetic coordinates on the map. Map could be referenced using only one point (in that case it is considered that measurement unit is 1 pixel and axes coincide. If there are two points, the map will be scaled and rotated, in case of three points affine transformation will be applied), but for accuracy control you should measure at least 4 points. To measure point put marker on point’s place on the map and push the button (**Add point**). After that, point’s name and pixel coordinates will be added to the list below the map. Input geodetic coordinates of the point to appropriate cells manually. When fifth point is measured, coordinates measurement errors E_X and E_Y will be automatically calculated and saved to the last column of the list below the map.

To edit coordinate value in table cell you should select the cell and press **F2**. To end editing and save coordinate press **Enter**, to exit from editing without coordinate save press **Esc**.

When georeference is completed push the button (**save**) to save georeference file in MapInfo format.

You can use georeferenced raster map to add points on project images. See also the chapter Adding points from a raster map.

4.3 *Automatic tie points measurement*

PHOTOMOD system provides performing of tie points measurement and relative orientation in automatic mode. Automatic mode uses correlation algorithm for tie points search and measurement.

Automatic mode of tie points measurement provides ample opportunities for relative orientation of images block – choice of optimal parameters to measure, adding and filtering of tie points using different criteria allows to reach required accuracy and substantially reduce time of project processing on relative orientation stage. Repeated ties measurements in automatic mode along with correction of parameters values, as well as manual mode using for measurements refining and errors handling guarantees excellent results on block adjustment stage.

4.3.1 Working order and terms

Automatic tie points measurement procedure requires the following data:

- interior orientation of all images, that will be used in automatic tie points measurement (see the chapter Interior orientation)
  Note: It is highly recommended to perform interior orientation, since otherwise most filtering parameters will be not applied during automatic ties measurement, and thus the quality of relative orientation in automatic mode is not guaranteed.
- Block layout
  Note: The sufficient condition for start of tie points measurement in automatic mode is creating of initial ("rough") block layout, considering, for example, images overlap data and/or manual matching data. Nevertheless, the more data is considered for block layout creation, the more accurate is block scheme, and correspondingly, the better results of automatic ties measurement.

Working order on ties measurement in automatic mode includes the following operations:

- Create block layout considering available data (see the chapter Block layout).
- Set up parameters of points measuring, transfer, filtering, and start automatic ties measurement (see the chapter Performing of automatic tie points measurement).
- Estimate relative orientation accuracy to detect tie measurement errors (see the chapter Relative orientation report).
  Note: For relative orientation accuracy analysis you can also perform block adjustment and estimate errors of ties measurement on the Images tab (see the "Block adjustment" User Guide).
- Remove ties measurement errors manually in the **Points measurement** module (see the chapter Manual measuring of triangulation points) or select other filtering parameters (e.g., by setting up more rigid acceptable error thresholds) and start automatic measurement once more.
- Refresh the block layout considering measured ties. Change parameters settings if necessary, and re-start automatic ties measurement for further collecting of tie points measurements. Repeat steps 3-4.

4.3.2 Performing of automatic tie points measurement

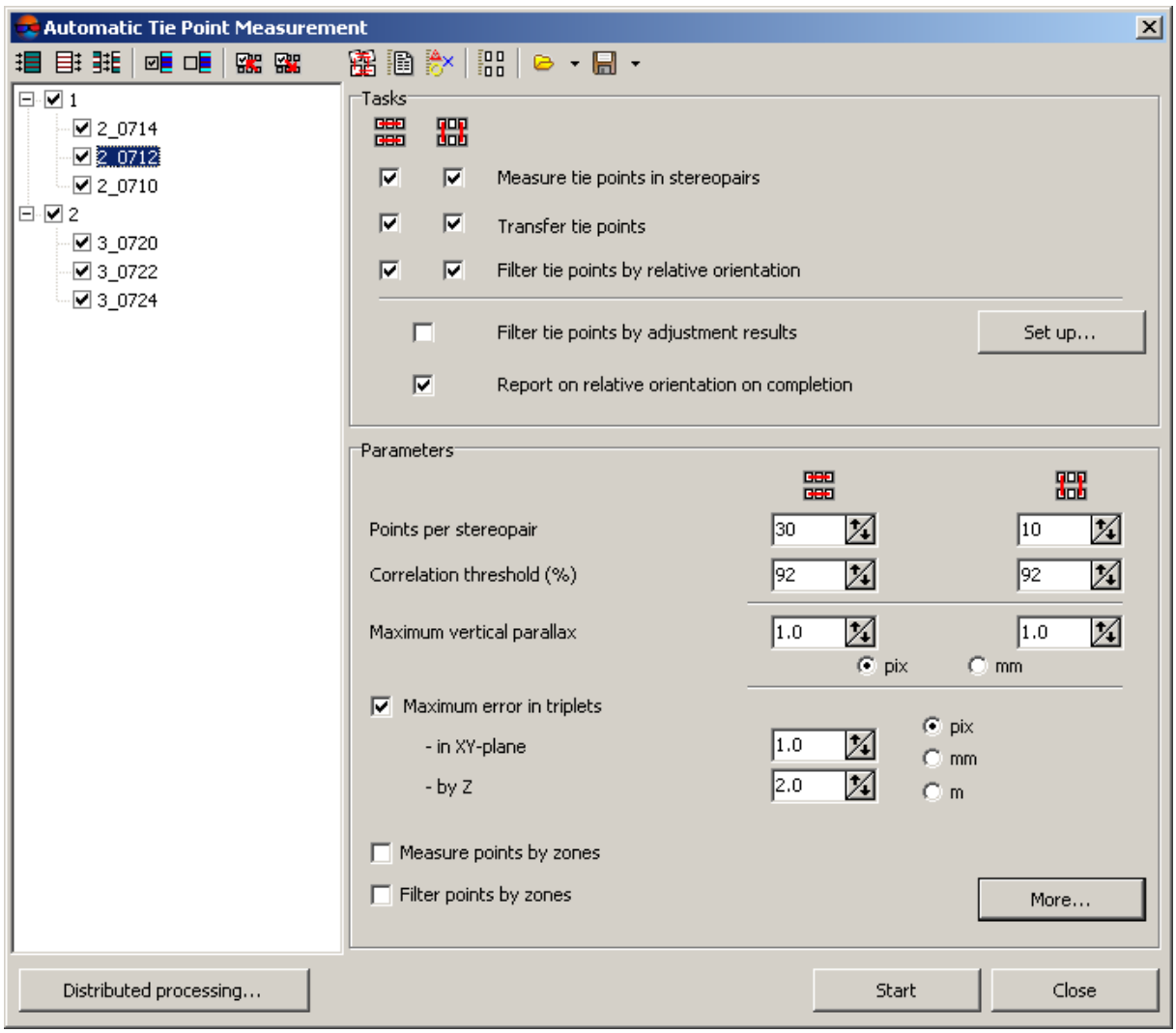
To perform automatic tie points measurement do the following:

– Use the parameter presets or specify manually all the basic actions / parameters for searching, measuring, and rejection of points in the Automatic tie point measurement window, as well as additional parameters to estimate the basic parameters and a more "fine tuning" in the **Tie point measurement parameters** window;
– launch automatic points measurement operation (by clicking the **Start** button in Automatic tie point measurement window)
– open Relative orientation report used to browse relative orientation results and edit measurements.

4.3.2.1 *Automatic tie point measurement window*

To perform tie points measurement in automatic mode click the button in the **Triangulation** toolbar or choose **Orientation | Automatic tie point measurement**. The appropriate window opens.

Note: The Automatic tie point measurement window allows using the parameter presets, set-up optimally, for aerial and UAV imagery or selecting manually the main and additional parameters for automatic searching, measuring and rejection of points.



Automatic tie points measurement window

The **Automatic tie point measurement** window contains the following interface elements:

- Toolbar for selection of images, opening the additional windows, saving and loading presets.
- The list of project images for selection of images for which automatic tie point measurement is to be performed.
- **Tasks** panel allows to specify actions which will be performed at start of automatic tie points measurement operation
- **Parameters** panel allows to specify a set of parameters, used during search, measurement, adding and filtering of points
- The **More** button is used for setup additional parameters of tie points measurement. See the chapter Additional measurement parameters
- The **Start** button used for launch of tie points measurement procedure in automatic mode and performing of relative orientation. To view the results of relative orientation operation open Relative orientation report.

- The **Distributed processing** button is used for automatic tie point measurement in the distributed processing mode. Opens the **Distributed measurement of tie points** window to define number of tasks.

The selection of images is performed in different ways. Set the tick opposite the image name to select a single image in the list. Set the tick opposite the image strip to select all images of the single stripe in the list. In addition, the toolbar contains the following additional tools for images selection:

- - allows to select all images in the list;
- - allows to unselect all images in the list;
- - allows to invert image selection;
- - allows to select highlighted images;
- - allows to unselect highlighted images.
- - allows to select image from the list, selected in the block scheme;
- - allows to select the images in the block scheme, which were selected from the images list

To *highlight* image in the list, click its name in the list. Use the **Ctrl** and **Shift** shortcut to *highlight* several images.

The following buttons are provided to open the additional windows in the toolbar:

- - is used for opening the Block layout window;
- - is used for opening the Report on relative orientation window;
- - is used for opening the Tie points list window;
- - is used for opening the AT module displaying images checked in the list (given that there are not more than 6 images checked).

The following buttons are provided for saving and loading presets:

- - push the appropriate button to load the saved before preset with *.x-ini extension. The drop-down menu button brings up a menu with the following items:
- **Load settings from file** – open the **Load settings** window to load the presets with *.x-ini extension from Windows file system;
- **Reset setting to defaults** – allows to use the presets by default;
- **UAV** – allows to load the preset, optimally chosen for UAV images;
- **Standard** – allows to load the presets, optimally chosen for aerial images.

- push the appropriate button to save the presets with *.x-ini extension.

Tasks panel contains two groups of parameters. The first group allows to specify the following operations:

- **Measure tie points in stereopairs** – allows to search and measure tie points on adjacent images of stereopairs.
- **Transfer tie points** – allows to transfer measured points on adjacent stereopairs (i.e. to transfer points, located in triple overlap zone, to adjacent models).
- **Filter tie points by relative orientation** – allows to filter points, which have measurements exceeding preset acceptable errors threshold. Points check for filtering is performed sequentially by types of errors – first for exceeding of correlation threshold, then for maximal value of vertical parallax, and finally for errors in triplets, if

the appropriate option is selected. At that, check for exceeding of correlation threshold is performed *only for new points* (if there are already measured points). If you need to check *all* measured points for exceeding of correlation threshold (usually on check completion), you should select an additional option **Delete points with correlation below threshold** on **Rejection** tab in Additional measurement parameters window.

Each operation (measurement, transfer and filtering) is setup individually for measurements inside strip (when the **Inside strips** checkbox is selected) and between strips (when the **Between strips** checkbox is selected).

The second group of parameters in the **Tasks** panel contains the following options:

- **Filter tie points by adjustment results** – allows performing automatic block adjustment with specified parameters and using its results for points filtering. Such a filtering is useful, for example, if there are blunders on images between strips. Filtering is performed using values of acceptable errors preset in **Parameters** window, opened by clicking the **Set up** button. Specify the adjustment method on the **Adjustment** tab and setup values of acceptable errors on the **Report** tab. If there are no GCP, you should use a free model as adjustment method, in this case it is recommended to setup the basis value as precise as possible. More details about **Parameters** window see in **Block adjustment** User Guide.
- **Report on relative orientation on completion** – opens the **Report** window used for viewing and editing of tie points measurements right after performing of automatic relative orientation. See the chapter Relative orientation report.

Parameters panel contains the following parameters:

- **Points per stereopair** – allows to set a number of points measured on each stereopair (the resulting amount of measured points on stereopair could be both more than this number (due to their transfer from adjacent stereopairs), and less than it due to the further rejection). Default number is 30 points inside strips, and 10 points between strips. Minimal number of points needed for control of residual vertical parallax – 6.
  Depending on the options on the **Miscellaneous** tab, the **Points per stereopair** parameter specifies either number of points to be added at each stereo pair in one session, (if the **Points to add per session** option is selected), or the target number of points, which must be measured at each stereo pair (if the **Target number of points on a stereopair** option is selected). I.e., for example, if there are 10 points already on a stereopair, and the **Points per stereopair** parameter is 30, there will be 30 points added in former case and 20 in latter case.

- **Correlation threshold** - the minimal acceptable value of correlation coefficient for tie point to be accepted during automatic search. Recommended value is 0.9 – 0.95. In contrast to all other rejection criteria this parameter influences on point measurement and transfer process directly. Check for exceeding of correlation threshold is performed only for new points (if there are already measured points). To check all measured points for exceeding of correlation threshold (usually, at final stage) you should select additional option **Delete points with correlation below threshold** on the **Rejection** tab in Additional measurement parameters window.
- **Maximum vertical parallax (in pixels or millimeters)** - threshold value for rejection executed after points measuring/transfer. On each step of rejection process, the program searches for the point with maximal Y-parallax on the stereopair and rejects it. After that, it makes relative orientation once more and the iteration is executed until maximal Y-parallax exceeds the parameter specified here, or until 6 points or less remain on stereopair. Recommended value is a pixel size.

- **Maximum error in triplets in XY-plane and by Z (in pixels, millimeters or meters)** - threshold discrepancy of points measurements on adjacent stereopairs in triple overlapping zone of adjacent images in a strip. Use the following formula to calculate values of acceptable errors in triplets:
  $E_{\max} \approx 2 \cdot E_{mean}$, where E_{mean} - acceptable mean error
  Mean triplet errors in XY plane should not be greater than half of pixel size multiplied by $\sqrt{2}$, error by Z equals the mean triplet errors value in XY plane multiplied by the ratio of focal length (f) to survey basis (b) (in image scale). See below:

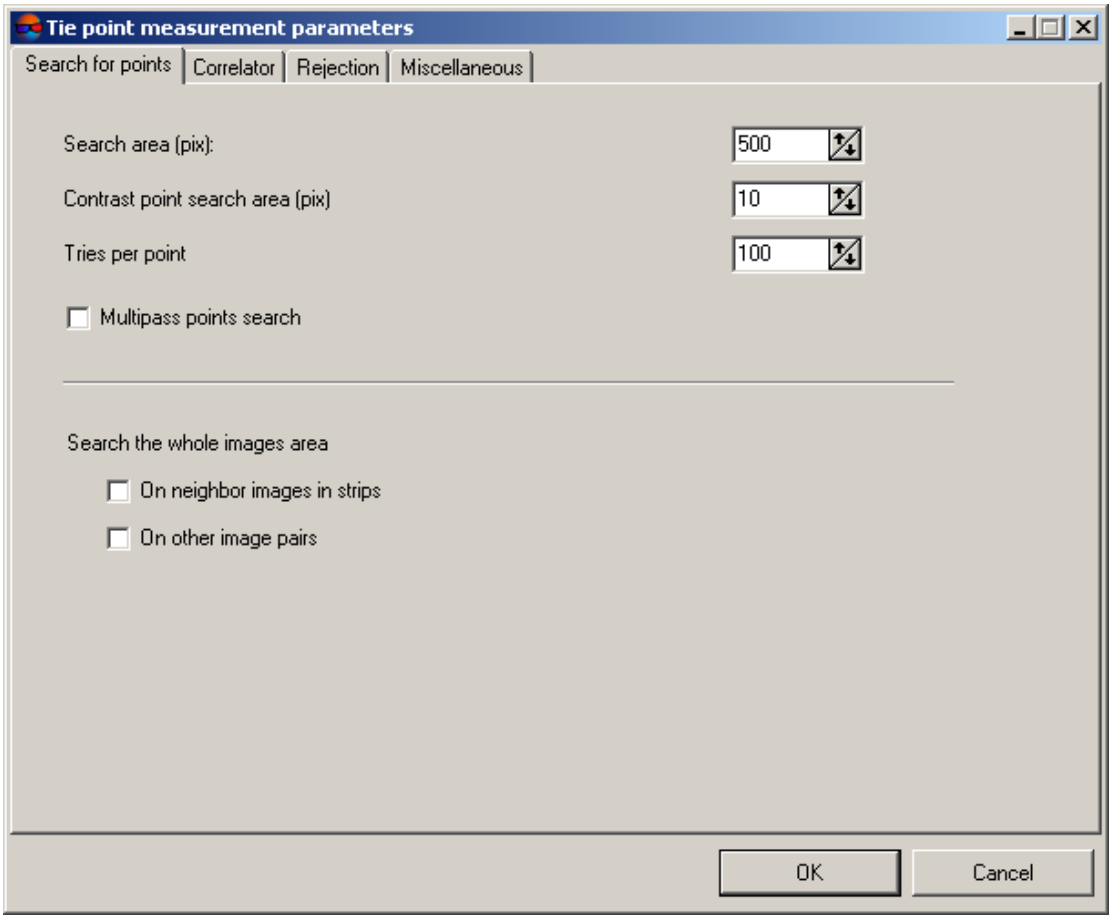
$$E^{xy}_{mean} = \sqrt{2} \cdot 0.5\, pxl$$

$$E^{z}_{mean} = \frac{f}{b} \cdot E^{xy}_{mean}$$

- **Measure points by zones** - allows to use a method of sequential measurement by zones of overlap area. Use **Zones** section on the **Miscellaneous** tab in Tie point measurement parameters window to adjust parameters of such zones. If the option is off, points are measured on the entire stereopair area uniformly.
- **Filter points by zones** - allows using zones on stereopair for filtering of measured tie points. The operation provides filtering the worst (by parallax) points on stereopair, passing zone by zone one after another. So the worst point on stereopair is found and deleted first, then the worst one in the next zone and so on. Uniformity of point's distribution on stereopair is also verified in such a way.

4.3.2.2 *Additional measurement parameters*

Use the **Tie point measurement parameters** window to specify the main parameters of tie point measurement and "fine" setting. This window opens using the **More** button in the **Automatic tie point measurement** window.



Tie point measurement parameters window

The window contains following tabs:

- **Search for points**
- **Correlator**
- **Rejection**
- **Miscellaneous**

The window consists of the following tabs:

Search for points – contains the following settings:

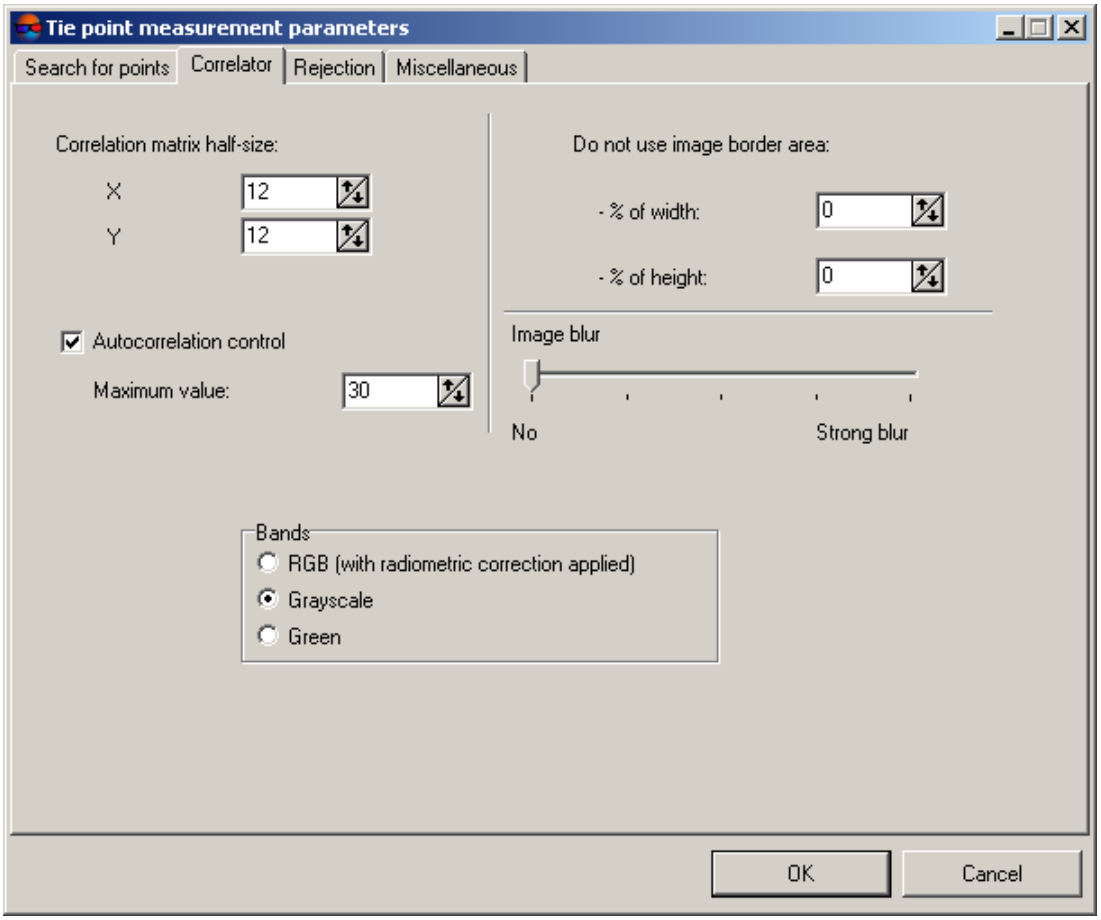
- **Search area (pix)** - searching area for areal correlator. It is setup depending on block layout accuracy. Typical values are from 10% to 30% of image size. Default value is 1000 pixels. Actual search area may be determined in the **Points measurement** module (see chapter Measuring the corresponding point search area); if actual value is larger than 1000 pixels, increase this parameter according to the measurement results.
- **Contrast point search area (pix)** - default value is 100. The parameter is used for tie points search in areas of maximal contrasts (images with clear object's features). In some cases it is advisable to measure points in areas with low contrast (for example, when maximal contrast corresponds to woods areas, where correlator errors have high probability). The parameter value may be reduced there up to 10 for example. In this case you should setup 0 value in this field.
- **Tries per point** - number of tries to calculate correlation for each point out of the amount set by the **Points per stereopair** setting on **Parameters** panel of the main window (100 – by default). Maximal amount of tries to found a point with correlation coefficient not less than threshold specified is a multiplication of this parameter by the **Points per stereopair** value.
- **Multipass points search** – allows making several passes for point measurement and filtering using different algorithms in case of insufficient quality of the block layout, when

real relative rotation of images differs from what is present in block layout. Usually this parameter should be used for UAV images.

- **Search the whole images area** – allows defining the stereopair for points searching: the neighboring images in the strips or other stereopairs (i.e., the non-neighboring pairs in the strip and inter-strip stereopairs).

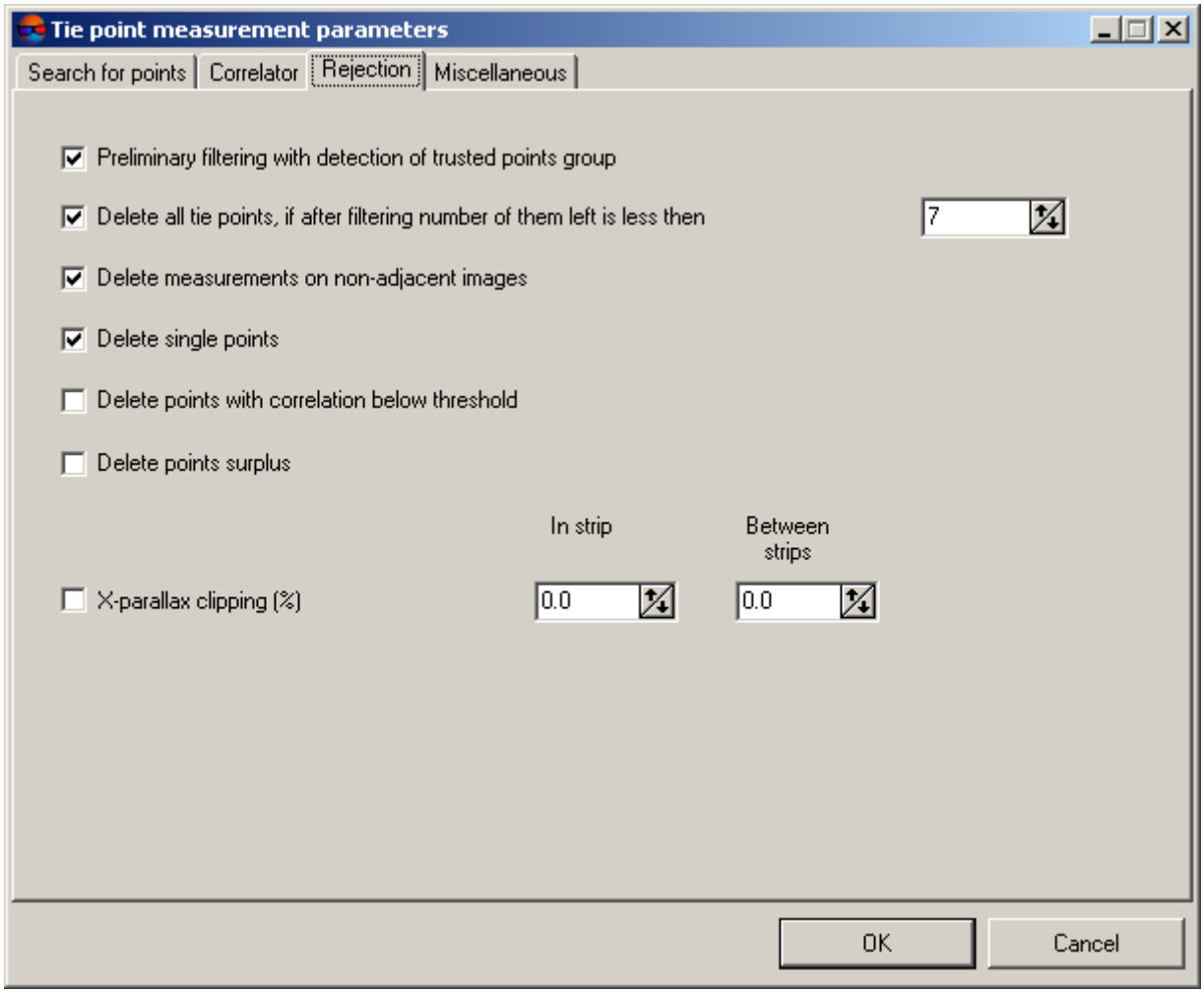
Correlator – the tab is intended for setting areal correlator parameters:

- **Correlation matrix half size** – size of correlation matrix by X and Y axes (measured in pixels).
- **Autocorrelation control** – I.e., the bigger the value, the less the reliability of points that will be collected by correlator with this point as initial one.
- **Do not use image border area** – is used for setting service information area with specified width near the image edge should not be used for correlator work. Service area width (2% of image width and height by default) should not be less than on the image; otherwise a big amount of wrong points would be measured in image service areas.
- **Image blur** – slider, which allows taking into account the images quality.
- The **Bands** section contains three parts: **Grayscale** (by default), **RGB** and **Green**. The **RGB** option can be activated for tie point calculation on the color images. It can enhance measurement accuracy, but increase the work time of automatic calculation. Activation of the **Green** option is recommended for low quality images from UAV



Correlation parameters

Rejection tab is used to setup point's filtration parameters:

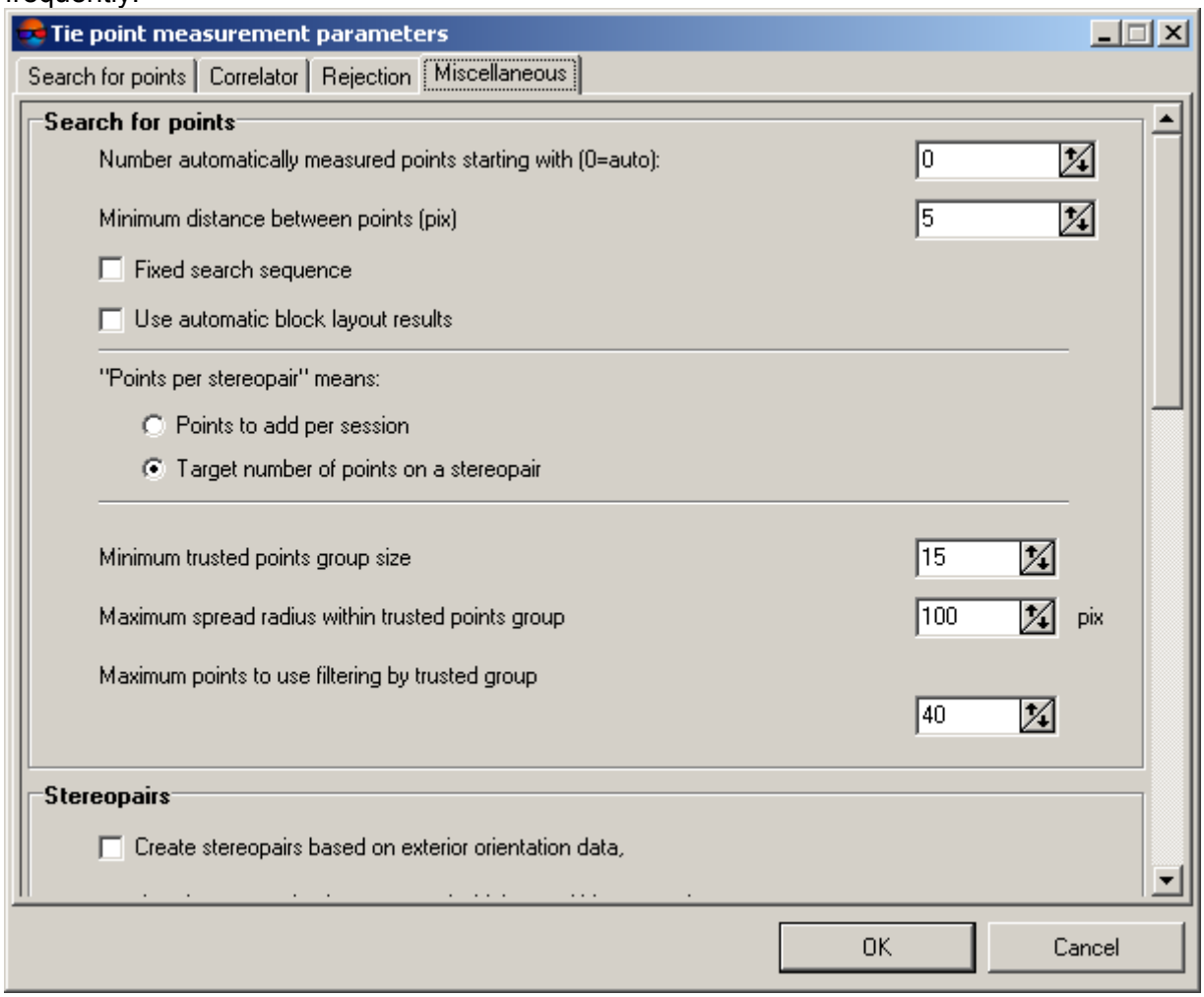


Tie points filtration parameters

- **Preliminary filtering with detection of trusted points group** – is used for preliminary filtering of blunders, which are do not allowing to compute relative orientation angles correctly (see the trusted points group parameters on the **Miscellaneous** tab).
- **Delete all tie points, if after filtering number of them left is less then** – when the option is active, the system deletes all measured points on the stereopair, if the relative orientation cannot be calculated correctly. It is likely that some (or all) points on the stereopair, in this situation, are erroneous, and removal of them would improve the overall quality of the block orientation.
- **Delete points with correlation below threshold** – when there are tie points measured automatically using correlator, you can filter these points after specifying the threshold value in the Automatic tie point measurement window. It is suitable to use the option for recurrent or final point's filtration, since the filtering covers *all* measured points, not only new ones, added during recurrent start of automatic tie points measurement operation.
- **Delete single points** – allows to filter and delete points measured on single images.
- **Delete measurements on non-adjacent images** – allows to filter potentially erroneous points, measured on non-adjacent images inside a strip.
- **Delete points surplus** – make the system delete points above the quantity, specified by the **Points per stereopair** parameter in the **Automatic tie point measurement** window, sorted by the Y-parallax in descending order. The tie points are evenly deleted, if the **Filter points by zones** option is checked. It is recommended to use after the initial tie points measurement for UAV project.
- **X-parallax clipping (%)** – number of points with minimal and maximal x-parallax (relatively to total amount of points) which will be deleted. You should apply this rejection method if erroneous points are dispersed clearly along stereopair basis (if, for example, a

highway with bright marking goes in parallel to survey basis and correlator puts points on marking line elements, which do not correspond with each other).

The **Miscellaneous** tab contains some additional settings which are not needed to change frequently.



Additional parameters

The **Search for points** section contains the following parameters:

- **Number automatically measured points starting with** – is used for automatic numbering of measured tie points starting with number, specified in the entry field. It allows to distinguish these points from the ones already measured on the project images. Regardless of the set value, the system does not generate points with duplicate numbers. If the point with some number already exists, then this number will be skipped when creating of new points.
- **Minimum distance between points (pix)** – minimal distance in pixels between points measured on the image (5 – by default). It is recommended to increase the value of this parameter, when the problems with block adjustment.
- **Fixed search sequence** – If this option is checked, the sequence of images areas searched for points is fixed. Otherwise, the system tries different random image spots each run. The former case (fixed order) may be useful, for example, for performance testing; the latter (random order) is best for everyday practice.
- **Use automatic block layout results** – allows to use the block layout results, automatically created for UAV images.
- **«Points per stereopair» option button** specifies either number of points to be added at each stereo pair in one session, (if the **Points to add per session** option is selected), or the target number of points, which must be measured at each stereo pair (if the **Target number of points on a stereopair** option is selected). I.e., for

example, if there are 10 points already on a stereopair, and the **Points per stereopair** parameter is 30, there will be 30 points added in former case and 20 in latter case.

The next section defines so-called "trusted group" settings. The concept of trusted group is used for rejecting points as described below (see **Preliminary filtering with detection of trusted points group** parameter on the **Rejection** tab). A group of points is considered trusted, is it complies with the following two conditions:
1 condition: the distance between the point on the one image and the corresponding point on another image no more than a specified the **Maximum spread radius within trusted points group** parameter.
2 condition: number of points, satisfying the condition 1, no less than specified value in the **Minimum trusted points group size** entry field.
If a trusted group has been found, it supposedly means that initial relative orientation has been computed correctly and in this case, the point's rejection can be applied by these data. Otherwise, the rejection of points will not be executed, even if the **Preliminary filtering with detection of trusted points group** parameter is checked on the **Rejection** tab.
The **Maximum points to use filtering by trusted group** parameter specifies the limitation on the number of points to reject. It is recommended to set this value to 40-60 points. It is not recommended to set more than 60 points.

The **Stereopairs** section contains the following parameters:

- **Create stereopairs based on exterior orientation data, from images, projection centers of which are within range of** – if this option is not checked, the "nearest image" principle is implemented for composing stereopairs; if this option is checked, the stereopairs will be composed from images, projection centers of which are located at the distance no more than a specified value (in meters)
- **From different strips only** – if this option is checked, the instrip stereopairs will not be considered. Otherwise, all instrip stereopairs will be considered, including the nonadjacent.

The **Zones** section is used for defining zone size on the stereopair, in which the automatic search and tie points measurement is to be performed. The Relative orientation chapter contains info about the recommended zones.

The **Points transfer** section – allows estimating the initial approximation, as well as turning on the automatic transfer of *manually* measured GCPs and tie points along with automatic measured points.

The **Rejection by angle** section is intended for setting the filtration parameters of measured points from the images relative orientation.
In some cases, after the automatic tie point measurement, the images from the block can be rotated. And images relative orientation can be calculated incorrectly because of erroneous points. The probable rotate of images can be prevented. Turn on the filtering of measured tie points by the values of the angle rotation. In this section the value of angles (in degrees) for each of the elements of the stereo pair can be changed. Then tie points, which lead to excess of threshold values of the angles after the recalculation of the images relative orientation, would be filtered.
It is not recommended to use this method of rejection for blocks, in which the images can actually be rotated to each other. In this case the correctly spaced tie points would be removed.
Push the **OK** button for returning in the Automatic tie points measurement window after setting the presets.
Push the **Start** button for starting the searching, measuring and rejecting of points in automatic mode.
Open the Relative orientation report for viewing and editing results of the automatic tie point measurement.

4.4 *Manual measuring of triangulation points*

PHOTOMOD system allows to perform tie points measurement in manual mode, to measure ground control points, to edit erroneous measurements, acquired by automatic points measurement. For these operations, the system offers Points measurement module, which provides a wide range of possibilities for triangulation point's measurements and performing relative orientation.

4.4.1 **Points measurement** module

Points measurement module is used for triangulation points (ground control, check and tie) measurement in manual mode. At that during tie point measurement, relative orientation parameters are calculated automatically.

Points measurement module may be used on the following steps of project processing:

– input/measurement of ground control points (see the chapter Input and measuring of ground control points);

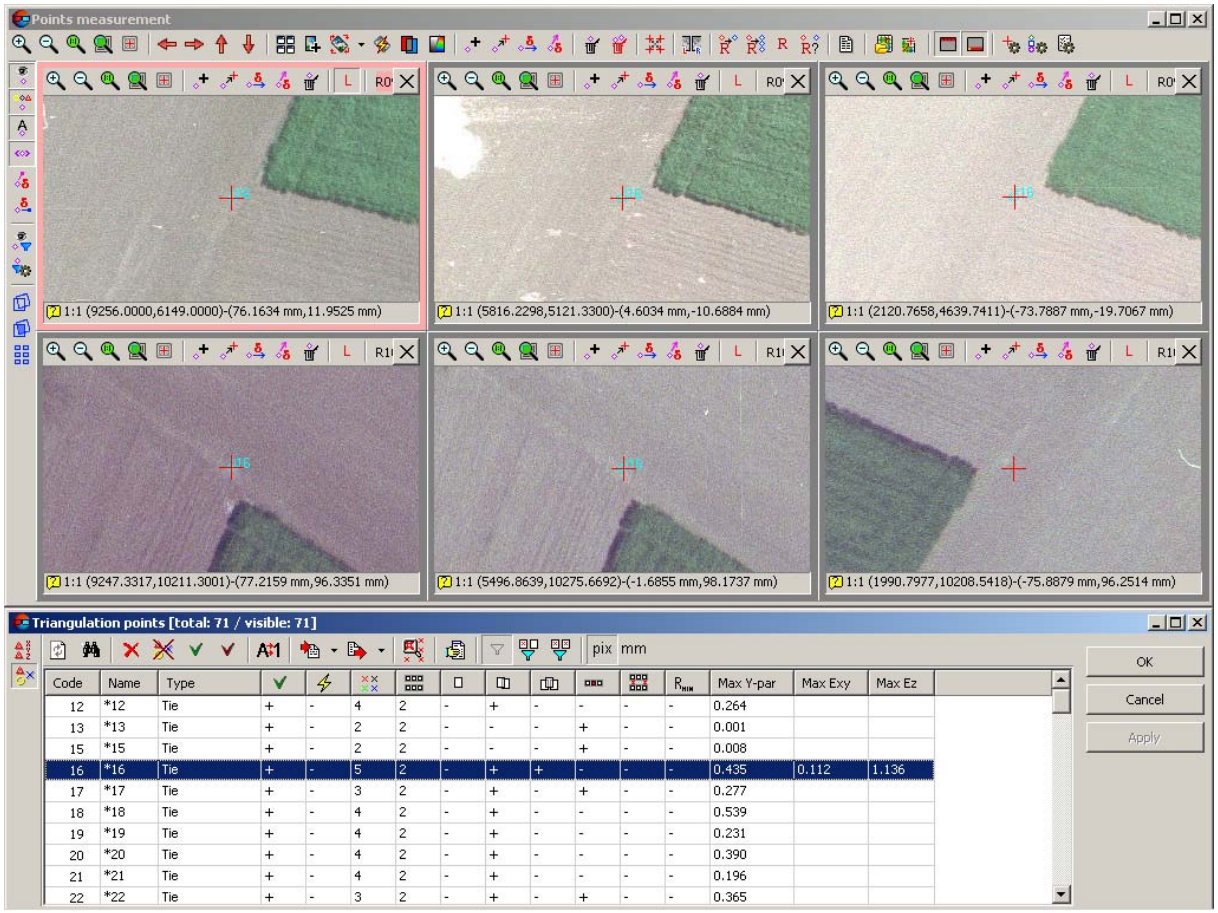
– measurement of tie points on block images in full manual mode and relative orientation perform;

– editing of tie points for correction of errors, appeared after measuring and performing of relative orientation in automatic mode (see the chapter Automatic tie points measurement);

– editing of triangulation points for correction of errors, appeared on block adjustment stage. See **Block adjustment** User Guide.

– tie points measurement for accuracy evaluation by Y-parallax after import of exterior orientation parameters. See the chapter Import of exterior orientation parameters.

Relative orientation module is *integration of two windows:* main window **Points measurement** and **Triangulation points** window. Main window of Points measurement module shows selected images in separate windows and contains tools for operations of triangulation points measurement. Triangulation points window is a list of all measured points of images block with measurements data and contains tools for work with the list.



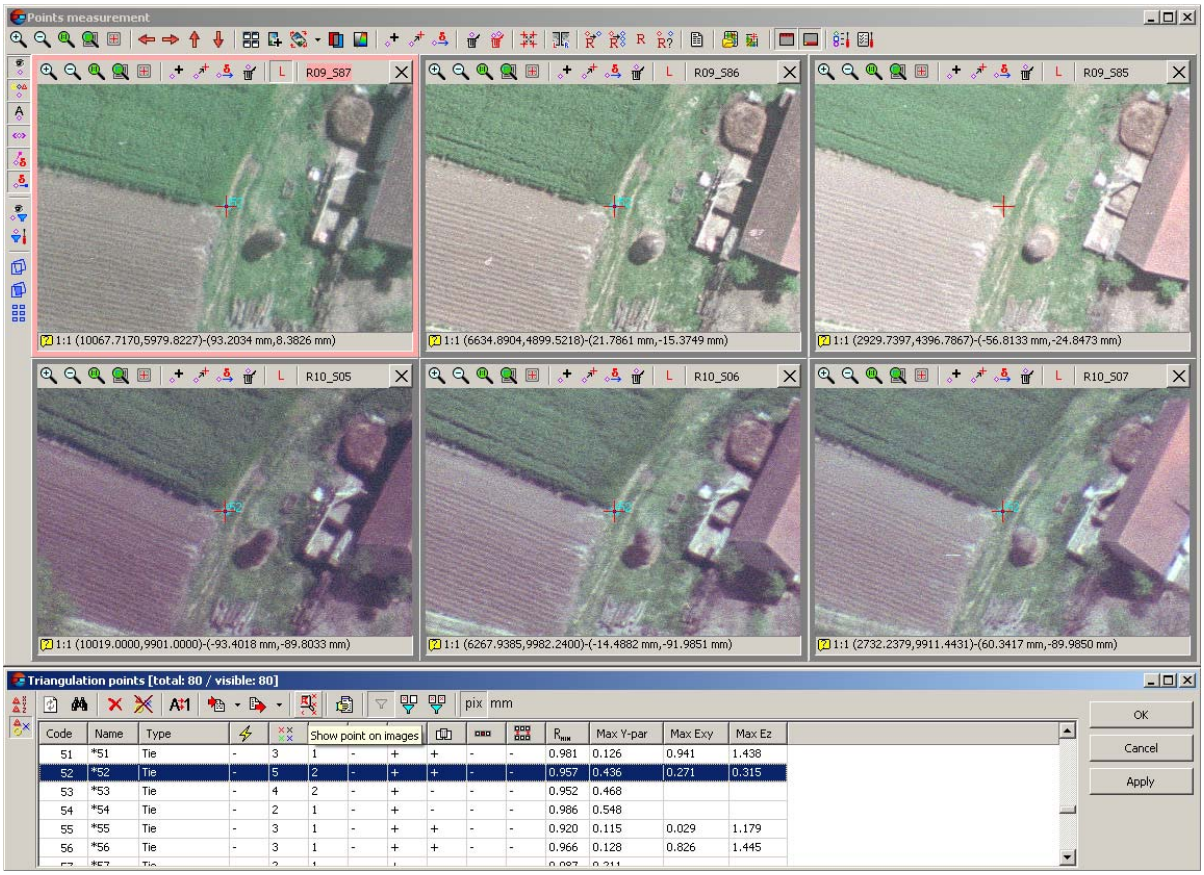
Points measurement module – combination of two windows: Points measurement and Triangulation points

Features of the **Points measurement** module

Work in both windows is *synchronized*. That means that during work in the module you will face the following:

- If you select a point on *image by double click*, this point will be automatically selected in the list and в shown in *opened* images windows, if it is measured on these images
- If you select a point *in the list by single click*, this point will be automatically shown in *opened* images windows, if it is measured on these images
- If you select a point *in the list by double click* (or by the button **Show point on images**), there are two cases possible:
  - *all images windows*, *where the point is measured* are opened;
  - *all images windows*, *where the point is measured or could be measured* (with marker located in position of supposed measurement) are opened. See also the button description in the chapter Triangulation points window.

In example on figure below the point is already measured on 5 images, and one image is opened where it could be measured.



View position of selected point in the list on image where it has been measured and on image where it has not been measured

Start of **Points measurement** module

To open **Points measurement** module use the following menu commands of **Orientation** menu item (duplicated by buttons of **Triangulation** toolbar):

- **Open selected images for measurement** (duplicated by the button) – opens **Points measurement** module and windows with images selected in **Block editor** or 2-D window
- **Open images containing marker** (duplicated by the button) – opens **Points measurement** module and windows with all images, containing a position of marker, placed in 2-D window
- **Open in-strip stereopair** (duplicated by the button) – opens **Points measurement** module and *two windows* with images of stereopair selected inside a strip. If you selected one image you will get opened its adjacent right image in the strip by default, if there is no right image – left image will open
- **Open inter-strip stereopair** (duplicated by the button) – opens **Points measurement** module and *two windows* with images of selected inter-strip stereopair. If you selected one image, you will get opened its adjacent lower image by default, if there is no lower image – upper image will open.

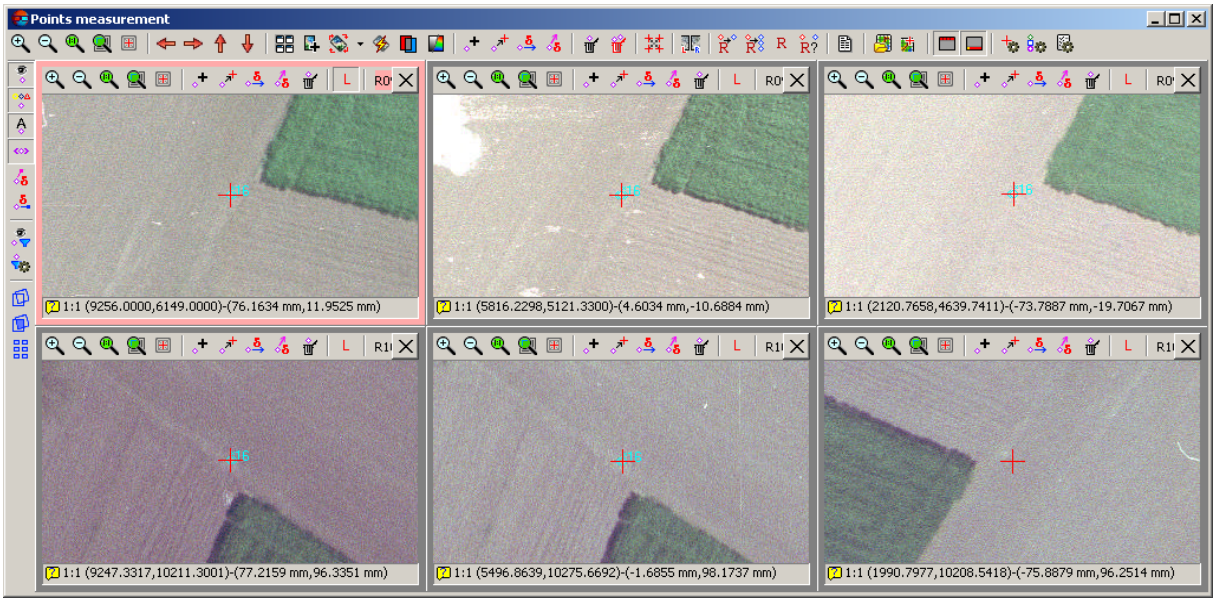
See also description of Main window of Points measurement module, and Triangulation points window.

Relative orientation procedure

After measuring of each new tie point relative orientation of images is performed automatically (vertical parallax is calculated for measured points). To view relative orientation results push the button **Report** in the list window. The relative orientation report is opened in *read only mode* and according to parameters, specified before in the **Relative orientation report settings** window. See also the chapter Relative orientation report. You can also open a report with relative orientation results only for opened images. Use for that main toolbar button of **Points measurement** module.

4.4.1.1 *Main window of **Points measurement** module*

Main window of **Points measurement** module is intended for displaying, measuring and editing of triangulation points on opened images. Here you can measure points and change point's position on any image (re-measure it) manually or using correlator in mono or stereo mode.



Main window of **Points measurement** module

The window contains main toolbar and windows of selected images; each of them displays image and its name, and contains its own toolbar and status line.

Main toolbar buttons of **Points measurement** window are used generally for performing of different operations for all opened images:

– zoom in image in all windows.

– zoom out image in all windows.

– show image in original size 1:1 in all windows.

– fit image to window in all windows.

– center image on marker in all windows.

– shift one image left ("scroll" images in opened windows to the left).

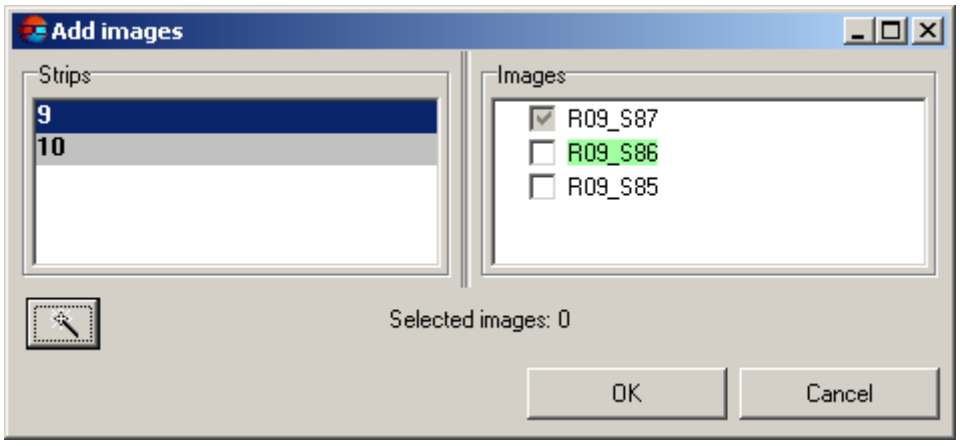
– shift one image right ("scroll" images in opened windows to the right).

– shift one image up ("scroll" up images in opened windows).

– shift one image down ("scroll" down images in opened windows).

– arrange windows – resize image windows left in the **Points measurement** window after closing some of them (to “fill in” the background)

– add images in new windows – opens the **Add images** window used for images selection



Adding images to the **Points measurement** module

You can select manually images to be added. Light green color indicates strips and images, which contain selected tie point (in the list or on opened images). To automatic selection of images that contain selected tie point click the button (**Select images automatically**).

– images transformations have effect on images displaying and on points measurement using correlator in **Points measurement** module. This tool provides images relative orientation (rotation and scaling) considering images location relatively to each other and scales difference in block scheme or in block layout data. Click the button to select one the following options in drop-down list:

- **No transform** – shows images as is
- **Rotation by block scheme, 90 - multiple** – allows to rotate images at angle, at which images were rotated during block forming in 2D window. The rotation angle is rounded to closest angle, divisible by 90
- **Rotation by block scheme, exact** – allows to rotate images at angle, at which images were rotated during block forming in 2D window
- **Block layout: rotation** – allows to rotate images according to block scheme
- **Block layout: scale and rotation** – allows to move images using rotation and scaling according to block scheme
- **Block layout: projective transform** – allows to rotate images using projective transformation (exactly as in block scheme)
- **Image scale** – allows to change basic scale of images for correlator. The same scale will be used for images displaying in scale 1:1.

– update block layout automatically as points are added (off by default). Affects images open in the module, i.e. only local block layout is recalculated.

– new stereo window – opens a stereo window for selected pair of images. Used for points measuring in stereo mode. See also the chapter Points measurement in stereomode. By default opens stereo image for the whole working area of **Points measurement** window (i.e. instead of all opened images windows). If you hold down the **Shift** key while clicking the button, stereowindow will open with size of two windows of images selected for displaying in stereo mode. If you hold down the **Ctrl** key while clicking the button, stereowindow will open with size of one window in position of the “left” image. Press **Esc** to close stereo window.

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– color/black-and-white images. Switch key for images displaying in color or black-and-white mode.

– add a tie point with measurements on all images. Adds a tie point to marker position on all opened images without correlation (you should position the point manually on all images).

– add or move selected point measurements to marker position on all images without correlation

– move point along tie error vector on all images. See also description of right panel buttons.

– move point along error vector on GCP on all images. See also description of right panel buttons.

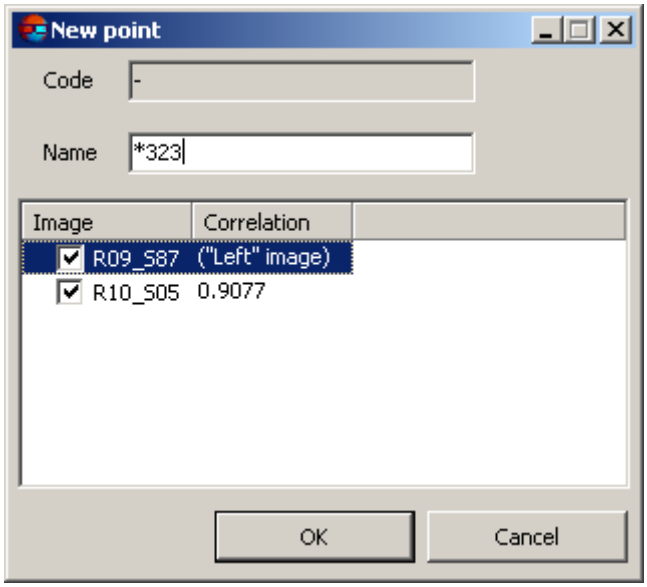
– delete measurements of selected point on all images, where it is measured.

– delete filter. Opens the **Delete point measurements** window allowing to select criteria of points filtering for deleting. Duplicated by menu command **Orientation | Delete point measurements**. See description in chapter Point measurements deletion.

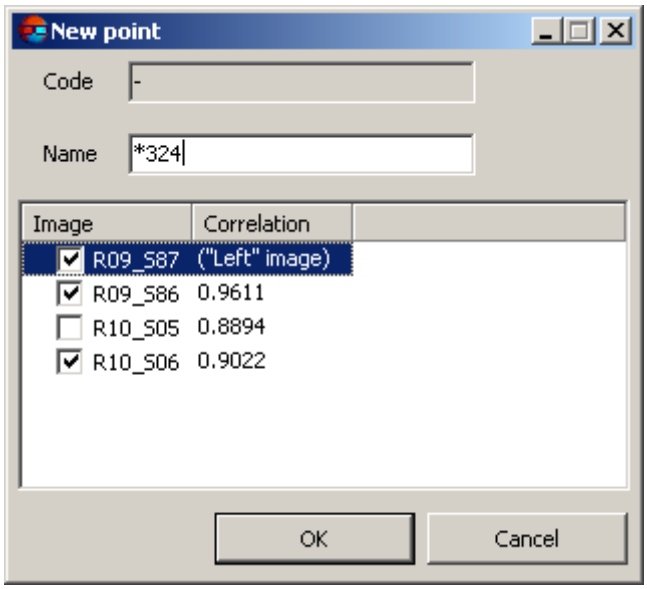
– synchronize markers on all images – searches for the same marker position on all open images, as on the selected image. For synchronization you need block layout data. So the more data used for block layout creation, the more precise positioning of marker. I.e. the main point of synchronization is searching for the same place on other images and positioning of marker there.

– open stereopair. Select “right” image for specified “left” one (use the button in toolbar of the image window) and two images of a stereopair will open in the **Points measurement** window.

– correlate active image to “left” (duplicated by the **Space** key). Allows to measure a new point *on two images* using correlator. For that you should set as a “left” one of images using the button in image window toolbar and show by marker the point’s position to be measured. On another image it is enough to show approximate point’s position. This tool opens the **New point** window. It shows point’s code, its default name that is editable using any symbols. Below you can see images list – left and active image with correlation coefficient of measured point. At that, if the correlation coefficient is not less than threshold value specified in the Parameters of points measurement ( ) window, the active image will be automatically checked in the list. If the correlation coefficient is too low ("bad point"), the image is marked in red. As a result, it is necessary to choose – either to add point on both images, if the correlation coefficient is satisfactory or to add point on left image only, or click **Cancel** to re-measure point.



– correlate all images to “left” (duplicated by **Ctrl**+**Space** shortcut). Allows to measure a new point on all images using correlator. For that, you should set as a “left” one of images using the button in image window toolbar and show by marker the point’s position to be measured. On another images it is enough to show approximate point’s position. You can consider block layout data and use the tool **Synchronize markers on all images** (see above). See above the description on how to search and measure points using correlator (the tool **Correlate active image to “left”**). In the case of points with correlation coefficient higher than the given threshold (in the Parameters of points measurement window), the images are checked; if the coefficient is too low, the images are marked in red (i.e. "bad point").



– show correlation for all images to “left” – shows correlation coefficient in status line of each image window, and in “left” image status line – autocorrelation coefficient (AQ).

– correlation analysis. See the chapter Analysis of autocorrelation coefficient.

– opens relative orientation report for opened images. See also the chapter Relative orientation and accuracy control.

– map. Opens the **Map** window where you can load a map (vector, raster or DEM), that allow to move GCP from geo-referenced map to images. See also the chapter Adding points from a vector map.

– find on map. Allows to display on geo-referenced map a position of marker in active window. See also chapter Measuring control point on map.

– Adding of GCPs panel. Allows to open the **Add GCPs from map** window to measure the GCPs from the georeferenced basis (raster and vector maps, DEMs) to the images. See also chapter Adding to list and measuring of GCP on the project images.

– toolbars. Shows toolbars in images windows. See the chapter Windows of opened images.

– status bars. Shows status bars in images windows. See the chapter Windows of opened images.

– marker settings. Opens the **Marker settings** window to set up the marker (shape, size and color).

– symbols. Opens the **Symbols** window, where you can select and setup symbols for displaying of different types of measured points. See chapter Symbols.

– settings. Opens the **Points measurement settings** window where you can specify correlator parameters and setup of report displaying after editing. See the chapter Parameters of points measurement .

On the vertical panel to the left there are the following tools used for images displaying management:

– show points. Shows all measured points on images in opened windows.

– show points with symbols. Shows all measured tie points by symbols, specified in accordance to their type in the **Symbols** window (see appropriate tool in the toolbar).

– show points names. Shows name labels for all measured tie points.

– show model arrows. Adds additional items to tie point symbol, directing to adjacent image (left or right), where this point was measured. For example, to triplet point symbol ◇ two items will be added to the right and to the left (◈), that mean connection with the left and the right image.

– show vectors of GCP errors. The feature is available after block adjustment. See **Block adjustment** User Guide.

– show tie error vectors. The feature is available after block adjustment. See **Block adjustment** User Guide.

– show error vectors. Blue color is used to show error vectors on GCP, purple color – on tie points. This option is available after block adjustment operation. See **Block adjustment** User Guide.

– turns on/off a filter to show points according to settings provided in the **Point filter** window (see below).

– setup points filter. Opens the **Point filter** window allowing to select certain type of points to display. See chapter Points filter.

– show overlap areas.

– fill overlap areas.

– show zones on overlap areas – allows to display 6 standard zones in overlap areas, recommended for tie points measurement.

4.4.1.1.1 Windows of opened images

In **Points measurement** module all selected images are shown in separate windows.

Image window in the **Points measurement** module

Each window with image contains a toolbar and shows image's name in upper part and in lower part – status bar. Depending on settings of points display, measured points are shown on image in certain way. Tools for points display are located in the main toolbar of Points measurement window.

Buttons of image window toolbar are similar to main toolbar buttons, but all operations are applicable just to image of selected window:

– zoom in image in selected window (duplicated by the ***** key).

– zoom out image in selected window (duplicated by the **/** key).

– show image in original size 1:1 in selected window (duplicated by **Alt-1** shortcut).

– fit image to window in selected window (duplicated by **Alt-Enter** shortcut).

– center image on marker in selected window.

– add a tie point with measurement on selected image to marker position (duplicated by the **+** key).

– add or move selected point measurement to marker position (duplicated by the **Ins** key).

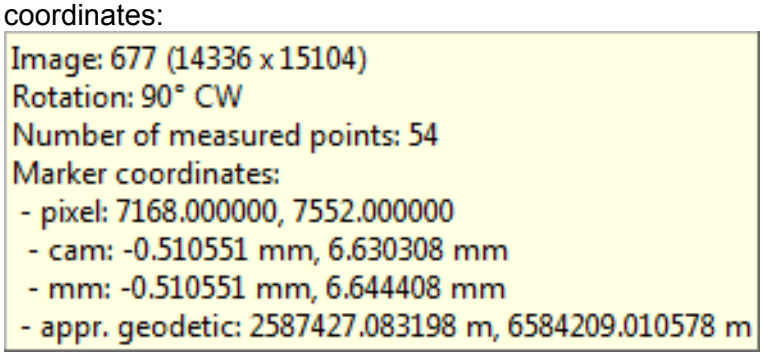
– move a point along tie error vector.

– move point along GCP error vector.

– delete measurements of selected point on the image (duplicated by **Del** key).

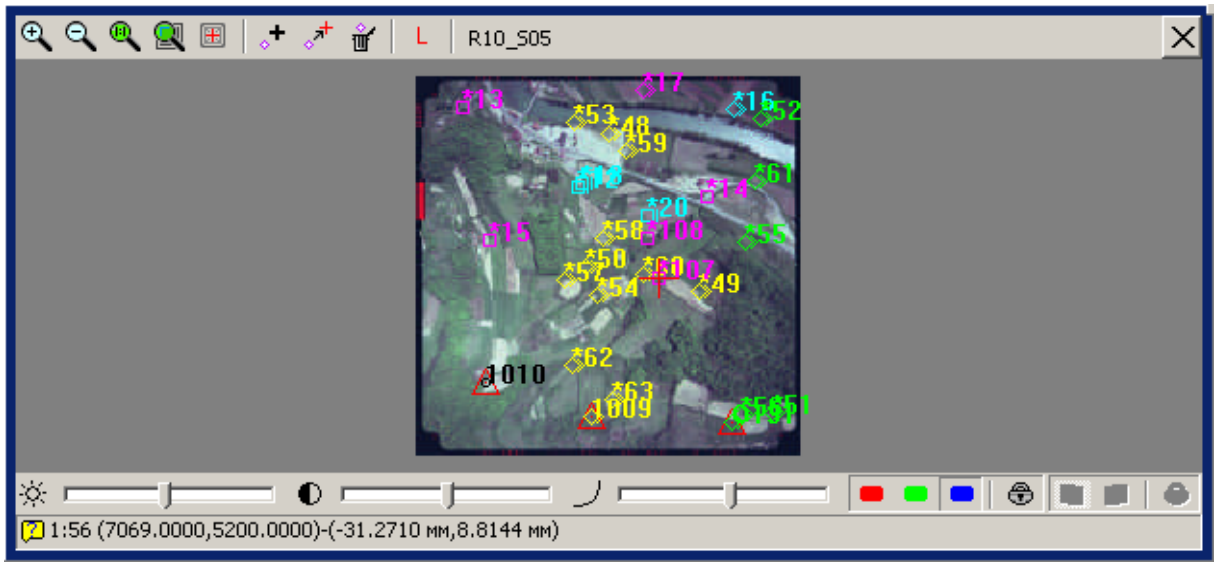
– select image as “left” (duplicated by **L** key). “Left” image is used to move points measured on it on other images and to measure points in stereomode (stereopairs creating).

Status bar or status panel display by default image scale in window, marker position coordinates (in pixels or mm), and additional information about image. To open the additional info panel place mouse cursor close to the icon. You will see a pop-up window containing info on image size and rotation angle, number of measured points and marker position coordinates:



When measuring tie points using correlator the status bar shows auto-correlation coefficient for left image and correlation coefficient for points measurements that correlate with the left image.

When you are working with raster image you can perform radiometric correction. To adjust an image radiometry, place marker on image and press **Shift+F8**. Tools for image adjustment will appear in status bar.



Radiometric adjustment of image

You can adjust the image’s brightness, contrast and gamma using corresponding sliders.

Scrollbars in active window may be turned on and off using **Ctrl+F8** hotkey.

Image panning is done with **Alt** key held down.

See description of stereo window for selected stereopair in the chapter Points measurement in stereomode.

4.4.1.2 *Triangulation points window*

Triangulation points window contains a *list* of all triangulation points of a project (ground control, check, and tie) with measurement data and also tools for points view, search, edit, and import/export.

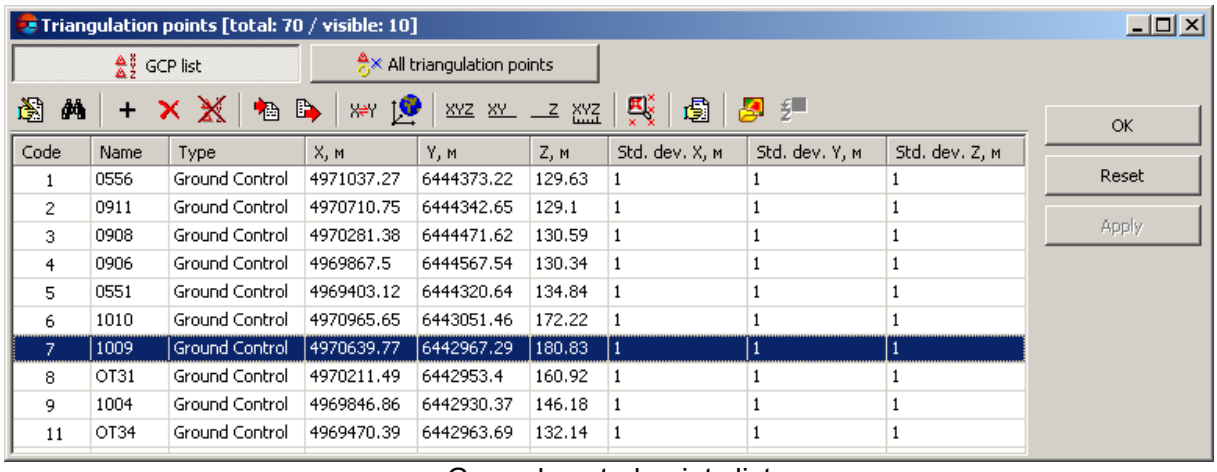
Triangulation points window is a part of Points measurement module and, moreover, may be used independently for work with just a list of points (for view, list editing, points import/export). During independent work with a list you can open **Points measurement** module with automatic displaying of a point, selected in the list on all images windows where it was measured.

You can open the **Triangulation points** window using the following ways:

- menu command **Orientation | Tie points list**. In **Triangulation points** window the **All triangulation points** tab will be opened, where you can see a list of all points of a project (ground control, check, and tie). Duplicated by the button of the main toolbar of **PHOTOMOD Core** and **Triangulation** toolbar.
- menu command **Orientation | GCP list**. In **Triangulation points** window the **GCP list** tab will be opened, where you can see a list of all input ground control points of a project. Duplicated by the button of the main toolbar of **PHOTOMOD Core**. See also the chapter Input and measuring of ground control points.
- during opening of **Points measurement** module. The **Points measurement** window is displayed in the lower part of the window. See the chapter Points measurement module.

Triangulation points window consists of two tabs – **GCP list** and **All triangulation points**.

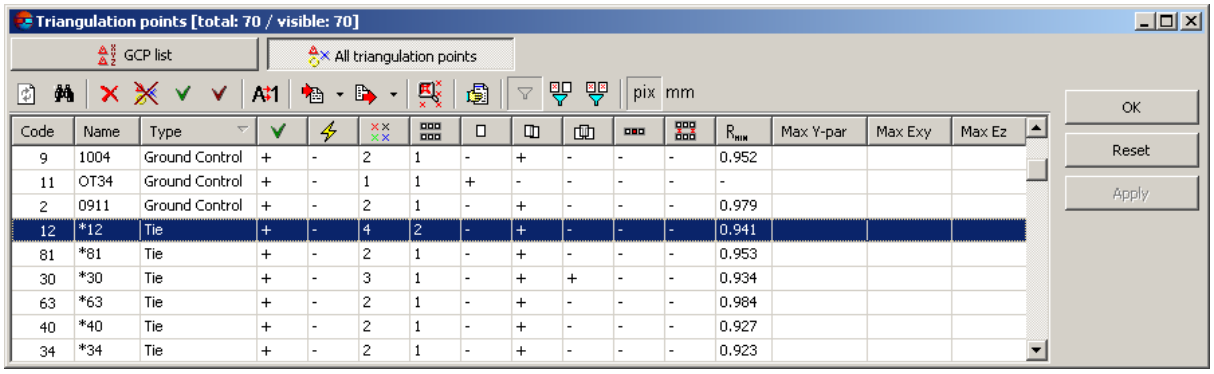
GCP list tab displays a list of ground control points with their coordinates and accuracy of their measurement on terrain. Toolbar buttons are used for input, view, search, edit, import/export of points, and visualization of selected points on images in Points measurement module. See also the chapter Input and measuring of ground control points.



Code	Name	Type	X, м	Y, м	Z, м	Std. dev. X, м	Std. dev. Y, м	Std. dev. Z, м
1	0556	Ground Control	4971037.27	6444373.22	129.63	1	1	1
2	0911	Ground Control	4970710.75	6444342.65	129.1	1	1	1
3	0908	Ground Control	4970281.38	6444471.62	130.59	1	1	1
4	0906	Ground Control	4969867.5	6444567.54	130.34	1	1	1
5	0551	Ground Control	4969403.12	6444320.64	134.84	1	1	1
6	1010	Ground Control	4970965.65	6443051.46	172.22	1	1	1
7	1009	Ground Control	4970639.77	6442967.29	180.83	1	1	1
8	OT31	Ground Control	4970211.49	6442953.4	160.92	1	1	1
9	1004	Ground Control	4969846.86	6442930.37	146.18	1	1	1
11	OT34	Ground Control	4969470.39	6442963.69	132.14	1	1	1

Ground control points list

All triangulation points tab displays a list of all measured points (ground control, check, and tie) with measurements data and toolbar used for search, edit and visualization of measurements on images in Points measurement module.



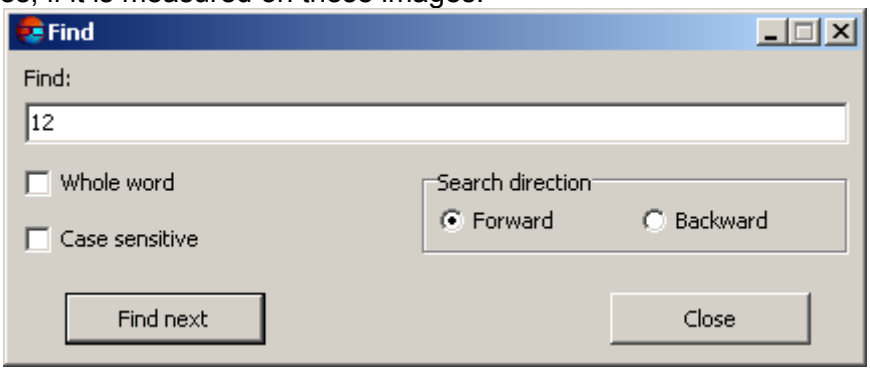
List of all triangulation points

Description of tools of **GCP list** tab see in the chapter Input and measuring of ground control points.

Toolbar of **All triangulation points** tab contains the following buttons:

– refresh list.

– find point. Opens the **Search** window that allows to search a point by its name. Input point name partly or in full, specify search direction and click the **Find next** button. Found point is selected in the list. In **Points measurement** module the found point is shown on opened images, if it is measured on these images.



– delete selected points from the list. Use **Shift** and **Ctrl** for group selection of points.

– delete all triangulation points (clear the entire list)

– use selected points as ties (if these points have been excluded before). The corresponding column shows "+" for the points. The excluded GCP will be used as tie only after this operation. To make such excluded point used as GCP, its type should be changed to **Ground Control** on **GCP list** tab.

– do not use selected points as ties, i.e. exclude these points from relative orientation calculation. The corresponding column shows "-" for the points. The points are not deleted. When a GCP is excluded, it is excluded completely – both as tie and as ground control.

– assign numeric names to selected points (rename points)

– import of triangulation points from PAT-B, X-Points format, and import from **PHOTOMOD** 4.x (XPT-file). See the chapter Triangulation points import.

– export of triangulation points to PAT-B and X-Points format. See the chapter Triangulation points export.

– Display on images the point selected in the list (duplicated by the double click on the point in list). In case the **Triangulations points** window is open without **Points**

measurement window, the Points measurement module opens. At that, if the **Automatically choose images containing point** option is turned on (see chapter Parameters of points measurement), then all images with the measured point, as well as images, where it can be measured at the position of the marker, are displayed. Otherwise, only images where the point has been measured are opened. Still, if this button is pressed with **Alt** key held down, the **Automatically choose images containing point** option is temporarily inverted.

Automatically choose images containing point option	(double click)	**+Alt** (double click +**Alt**)
Off	Open images with existing measurements of selected point	Open images containing projected position as well as measurements of the selected point
On	Open images containing projected position as well as measurements of the selected point	Open images with existing measurements of selected point

– show relative orientation report. Before report opening, the Relative orientation report settings window will be opened. See also the chapter Relative orientation report.

– show in **All triangulation points** list. This tool is available in **Points measurement** module.

– show points on opened images. Filter for displaying of those points in the list, which are located on opened images. This tool is available in the window in **Points measurement** module.

– show common points on opened images. Shows in the list only common points for all opened images. This tool is available in the window in **Points measurement** module.

– shows in the list values of vertical parallax and errors in triplets in pixels.

– shows in the list values of vertical parallax and errors in triplets in millimeters.

Points list is a table and contains the following columns:

Code	Name	Type	✓	⚡								R_{min}	Max Y-par	Max Exy	Max Ez
88	~91	Tie	+	+	2	1	-	+	-	-	-	0.959			
89	~92	Tie	+	+	4	2	-	+	-	-	-	0.924			
90	~93	Tie	+	+	3	1	-	+	+	-	-	0.969			
91	~94	Tie	+	+	2	1	-	+	-	-	-	0.942			
92	~96	Tie	+	+	3	1	-	+	+	-	-	0.940			
93	~97	Tie	+	+	2	1	-	+	-	-	-	0.930			
94	~98	Tie	+	+	2	1	-	+	-	-	-	0.975			
95	~99	Tie	+	-	4	2	-	+	-	-	-	0.933			
5	0551	Ground Control	+	-	1	1	+	-	-	-	-	-			
1	0556	Ground Control	+	-	1	1	+	-	-	-	-	-			
10	0904	Ground Control	+	-	5	2	-	+	+	-	-	-			
4	0906	Ground Control	+	-	1	1	+	-	-	-	-	-			
3	0908	Ground Control	+	-	2	1	-	+	-	-	-	-			
2	0911	Ground Control	+	-	2	1	-	+	-	-	-	-			
0	1004	Check	+	-	2	1	-	+	-	-	-	-			

Point list

- **Code** – point's code
- **Name** – point's name
- **Type** – point's type (tie, ground control, check, excluded)

- **Tie point included** - shows "+" if the point is involved in relative orientation, and "-" if the point is excluded from calculations. When the point is excluded, its row is grayed. When GCP is excluded, it is excluded totally – both as ground control and as tie, and its type becomes **Excluded**.
- **Point measured automatically** – shows “+”, if the point is measured in automatic mode (see the chapter Automatic tie points measurement), or “-”, if the point is measured manually
- **Total measurements** – shows number of images, where the point is measured
- **Strips with point measurements** – shows number of strips with point’s measurements
- **Measured on a single image** – shows “+”, if the point is measured on *single image* (has no ties) or “-”, if it is measured on several images
- **Measured in stereopairs** – shows “+”, if the point is measured on stereopairs, or “-”, if not
- **Measured in triplets** – shows “+”, if the point is measured in triplet, or “-”, if not
- **Strips with measurements on isolated images** – shows “+”, if inter-strip point is single in one of strips, or “-”, if it not single in a strip (i.e. is measured on stereopair or in triplet)
- **Measurements on non-adjacent strips** – shows “+”, if the point is measured on non-adjacent images, or “-”, if not
- **Minimum correlation coefficient** – shows correlation coefficient (minimum for all point measurements), if the point is measured using correlator
- Max Y-par **Maximum vertical parallax** – shows Y-parallax (in pixels or millimeters) when there are open stereopairs with computed relative orientation in Points measurement module.
- Max Exy **Maximum triplet error in XY plane** – shows error in triplet in XY-plane for a point measured in triple overlap (in pixels or millimeters) when there are open triplets in Points measurement module.
- Max Ez **Maximum triplet error by Z axis** – shows error in triplet in height for a point measured in triple overlap (in pixels or millimeters) when there are open triplets in Points measurement module.

You can sort the list by any column. To do it, click corresponding column header.

Error residuals after relative orientation:
Recommended acceptable threshold for correlation coefficient is 0.9-0.95.
Maximal Y-parallax should not exceed pixel size.
Acceptable residual for maximal error in triplets could be calculated using the following formula:

$E_{\max} \approx 2 \cdot E_{mean}$, where E_{mean} - mean error

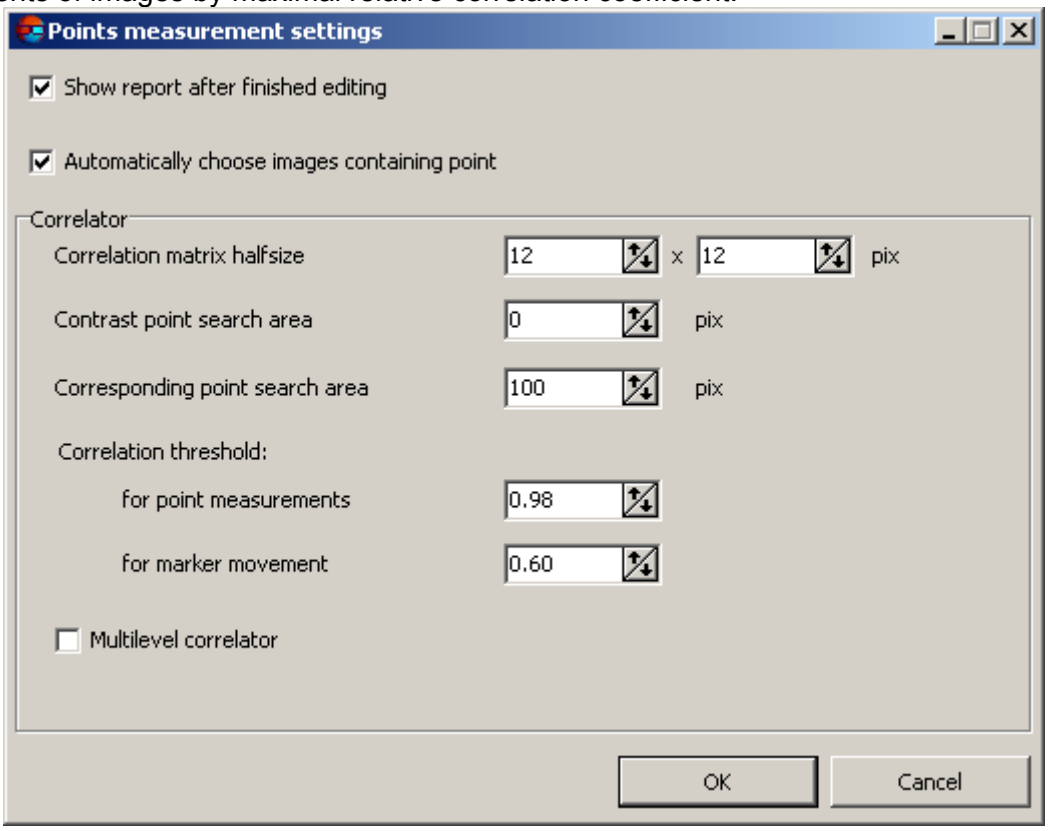
Mean triplet errors in XY plane should not be greater than half of pixel size multiplied by $\sqrt{2}$, error by Z equals the mean triplet errors value in XY plane multiplied by the ratio of focal length (f) to survey basis (b) (in image scale). See below:

$$E^{xy}_{mean} = \sqrt{2} \cdot 0.5\,pxl$$

$$E^{z}_{mean} = \frac{f}{b} \cdot E^{xy}_{mean}$$

4.4.1.3 *Parameters of points measurement*

PHOTOMOD system allows to search and measure tie points (identical points on images pair) automatically using correlation algorithm. The algorithm compares the corresponding fragments of images by maximal relative correlation coefficient.



Correlator parameters

The window contains common parameters:

- **Show report after finished editing** – opens a report after clicking **OK** button in Points measurement module.
- **Automatically choose images containing point** – this option defines the behavior of the **Show point on images** button in the Points measurement module. When it is on, image containing point measurements as well as not measured but predicted point positions are opened; otherwise only images containing existing measurements are opened. Using the button with **Alt** key pressed, the effect of this option is inverted.
  The following parameters are related to using correlator for tie points measurement (tools and of the main window of Points measurement module):
- **Correlation matrix halfsize** – allows to setup a size of correlation matrix by X and Y axes, expressed in pixels.
- **Contrast point search area** – defines an area (in pixels), where point with maximal contrast will be searched for. The parameter is useful for example, if initial raster data contains significant percent of monotonous areas.
- **Corresponding point search area** – defines an area around marker (in pixels), where the correlator will search for a point, corresponding to the point on the “left” image.
- **Correlation threshold** – this value is defined depending on initial image quality. The system searches for corresponding points, which correlation threshold value is *more*

or equals to preset **Correlation threshold for points measurement** value. These points will be shown automatically in the **New point** window (selected by tick). Points with correlation threshold which lies in *the range from preset threshold of marker moving to threshold of points measurement*, will also appear in the list, but they will be not selected in the **New point** window. You should estimate correlation coefficient and select images for adding new tie point. Points with correlation threshold less than the **Correlation threshold for marker movement** value, will be not considered for adding, and "Bad point" message will be shown.

- **Multilevel correlator** – is used for points search on resampled image (when a scale is less than 1:1).

4.4.1.4 *Analysis of autocorrelation coefficient*

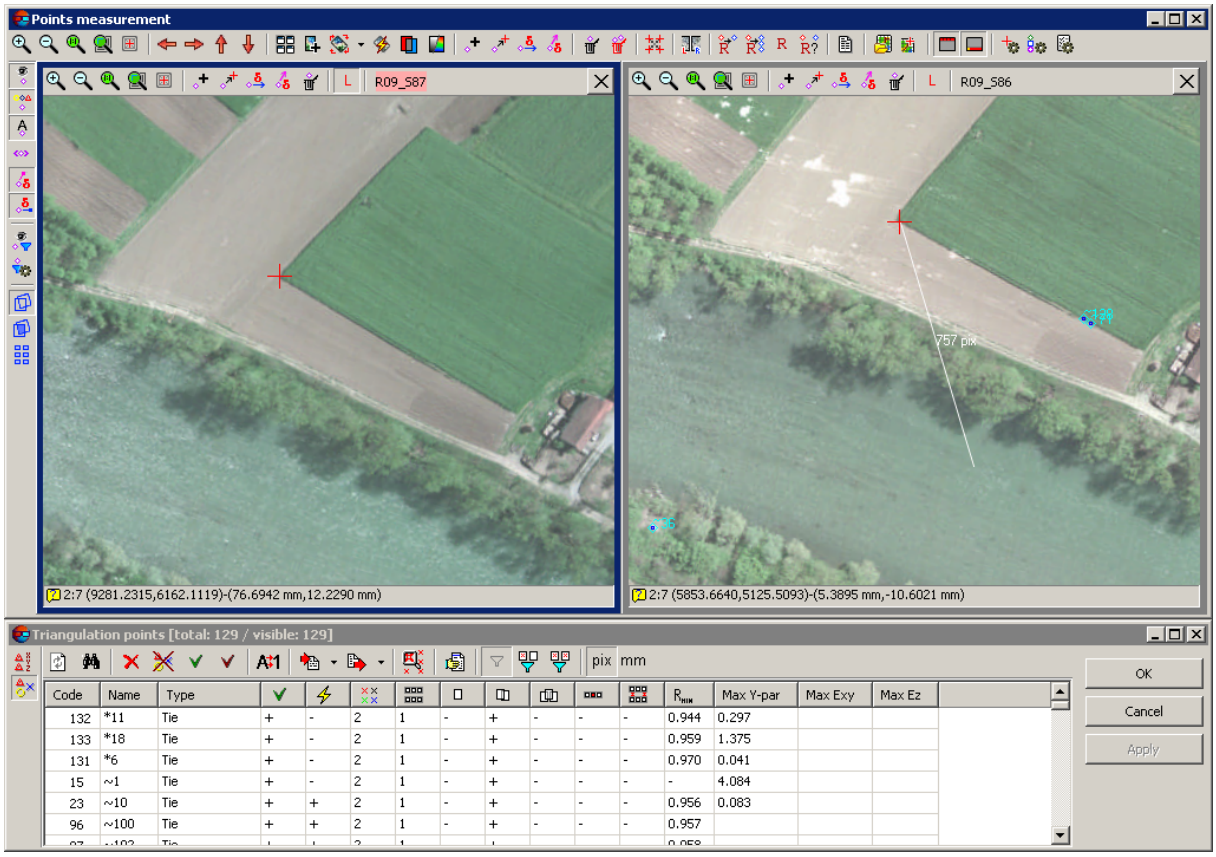
Note: This chapter is in development.

4.4.1.5 *Measuring correspondent point search area*

The **Points measurement** module contains a tool for estimating search area size for corresponding points, i.e. measuring discrepancy of image overlap, which can be large enough if block layout is no too exact, which in turn affects results of Automatic tie points measurement.
Assessment of this error allows taking it into account during automatic tie points measurement (see description of **Search area** parameter on Search for points tab in Additional measurement parameters).

In order to estimate the search area:

- open any stereopairs in Points measurement module. It is recommended to perform measurement on several in-strip as well as inter-strip stereopairs;
- double-click any image point inside the overlap area – marker on other images is placed in the estimated corresponding point position;
- measure the distance between actual corresponding point and the marker position using the **D** key: press first time to start measuring line (move marker to move second end of the line), press second time to end the line (exit distance measurement mode). The distance (measured in pixels) is shown as a label over the measuring line.



Measuring search area for the point chosen on the left image

4.4.2 Points measurement workflow

Note: This chapter is in development.

4.4.2.1 *Points measurement on a strip stereopair*

Despite the program being capable of measuring points on stereopairs in any order, it is recommended to perform measurement according to the order of images in a strip from left to right, to avoid confusion.

Note: This chapter is in development.

4.4.2.1.1 Measuring new points

Note: This chapter is in development.

4.4.2.1.2 Transferring existing points

Note: This chapter is in development.

4.4.2.2 *Points measurement on a stereopair between strips*

Note: This chapter is in development.

4.4.2.3 *Points measurement in triplets*

Note: This chapter is in development.

4.4.2.4 *Working in 4 windows*

Note: This chapter is in development.

4.4.2.5 *Working in 6 windows*

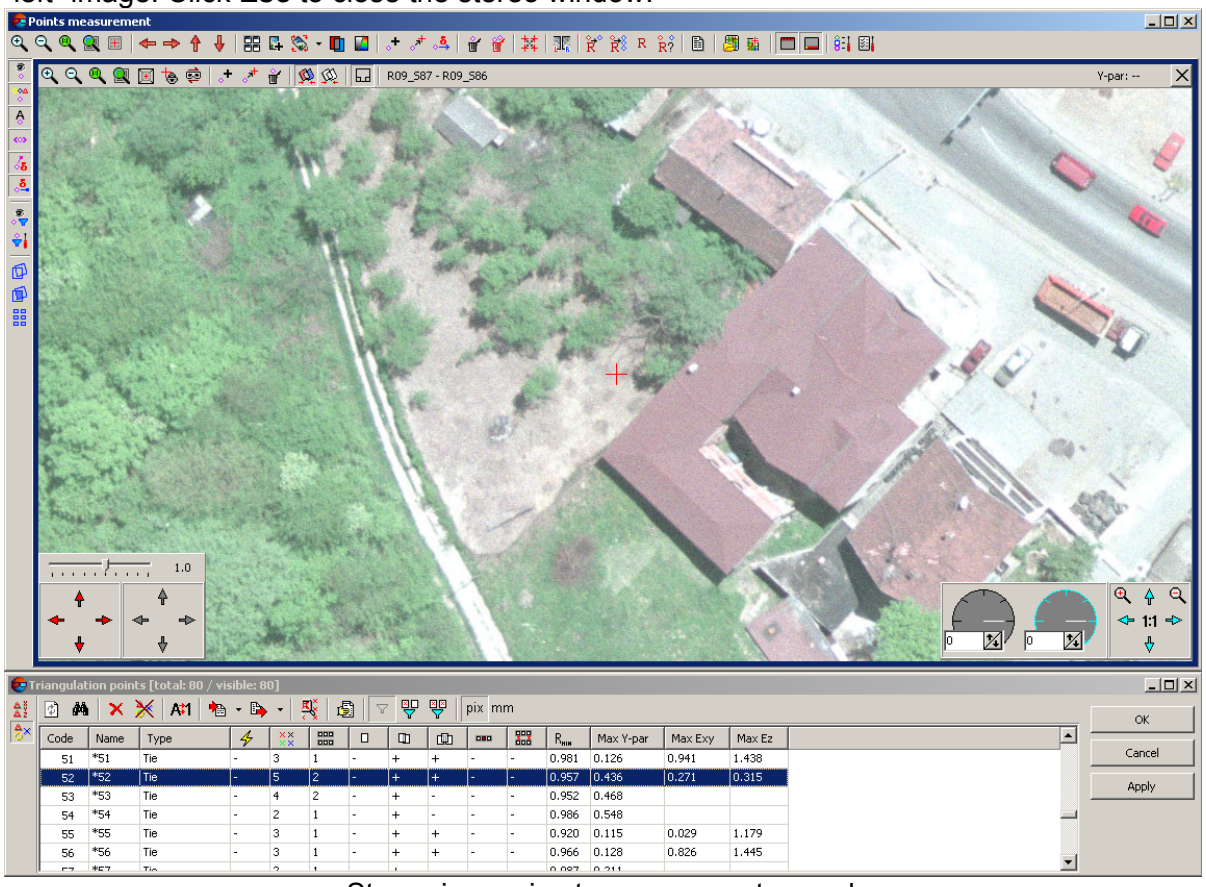
Note: This chapter is in development.

4.4.3 Points measurement in stereomode

Sometimes it is convenient to measure GCPs, check or tie points in stereo mode (for example, when points are located on vertical objects such as edges of roofs, columns, etc. or on the elements which are visible just on one image in mono mode – like on the bottom of inner corner of the building).

Points measurement module allows to perform measurements in stereo mode for selected stereopair. You can use two methods of stereo measuring:
– in *moving marker* mode
– in *fixed marker* in *stereocomparator*. Stereocomparator is set by default.

To open stereo image window select two images (left and active) that have overlap, show by marker *two identical points* on these images and push the button in main window of Points measurement module. By default stereo image for the whole working area of **Points measurement** window is opened (i.e. instead of all opened images windows). If you hold down the **Shift** key while clicking the button, stereowindow will open with size of two windows of images selected for displaying in stereo mode. If you hold down the **Ctrl** key while clicking the button, stereowindow will open with size of one window in position of the "left" image. Click **Esc** to close the stereo window.



Stereo image in stereocomparator mode

Stereocomparator mode allows you to move images (by mouse with pressed left button) while the marker is static and located at the middle of measuring window. The main

advantage of this kind of stereo measurements is that you can position the marker with sub-pixel accuracy. At that, the pixel size depends on the current zoom and the marker moving step is defined by the sensitivity slider located at the bottom of the window. Another advantage is that stereocomparator mode is available for adding or transferring tie points both in the stereopair overlapping area and in the inter-strip overlapping area.

Main tools of stereo window:

– zoom in stereo image.

– zoom out stereo image.

– show stereo image in original size 1:1.

– fit stereo image to window.

– center stereo image on marker.

– comparator mode – with maker fixed in a screen center (turns on by default at stereo window opening). Duplicated by **Ctrl**+**F6** shortcut.

– switch stereo phase (changes stereo phase, or swaps left and right images). Duplicated by **F11** hotkey.

– adds new tie point without correlation.

– move point into marker's position.

– delete measurement on stereo image.

– create epipolar images using points, if possible. You can create epipolar images (for which Y-parallax goes to zero), when there are at least five tie points measured on a stereopair.

– create epipolar images using adjustment results, if the results are available.

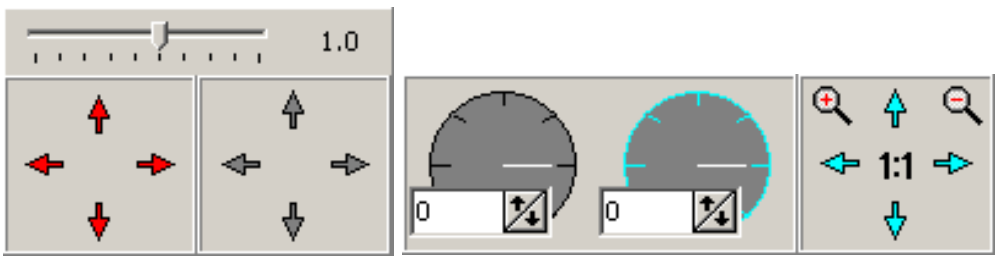
– show image control panels used for stereo image adjustment.

Then you can see names of images of opened stereopair and Y-parallax value in pixels (**Y-par**) in selected tie point. This parameter is available only during points measurements in images overlapping area (for stereopairs).

Image control panels are located in the lower part of the window and are used for images tuning and management of moving in the window.

Stereocomparator mode is used either for transfer of current selected tie point on adjacent image (by the button) or for measurement of a new tie point on images pair (by the button).

There are 3 groups of tools at the left and right part of stereo window bottom:



Left group of *red* arrows is used to move the *left image* in direction corresponding to selected arrow (duplicated by **Shift + arrow keys** of the keyboard).

Middle group of *grey* arrows (duplicated by **arrow keys** of the keyboard) is used to move *both images* together.

Right group of *light blue* arrows (duplicated by **Ctrl + arrow keys**) allows to work in the same way with the *right image*. Moreover, you can change right image scale using additional buttons on the right group of arrows:

- - zoom in right image scale on 5% or along with pressed **Shift** key on 1%;
- - zoom out right image scale on 5% or along with pressed **Shift** key on 1%;
- - **Reset** right image zoom.

The **Step** slider is used for adjustment of move sensitivity and is applied to mouse move, mouse wheel rotation and actions of keyboard arrows. Move step is changed from 0.1 to 20 of current screen pixel size (which depends on current zoom level). For quick selecting of the current step value use keyboard keys: **Ctrl+0**, **Ctrl+1**... **Ctrl+9**.

“Steering-wheels” are used for images rotation. Left “steering-wheel” is intended for both images rotation (by clicking on the wheel field or entering rotation angle value into numeric field). And right wheel – for right image rotation. If you would like to restore the initial image position use double click on the numeric field.

Besides, you can adjust the image brightness, contrast and gamma-correction for a single image or both images of a stereopair. For that press **Shift**+**F8** shortcut.

In the lower panel you will see stereo image correction tools. Tools located in the right part allow to select left, right or both images, and also color channels, which correction settings will be applied to. Corresponding sliders allow to change image brightness, contrast and gamma-correction.

To measure points in stereocomparator place marker on terrain surface, removing X-parallax using mouse wheel or horizontal arrows for moving left or right image. Add new tie point using the buttons , of stereo window toolbar. If calculated value of Y-parallax for this point is not satisfactory (maximal acceptable value of Y-parallax is 1 pixel), you should re-measure the point using mouse wheel along with pressed **Ctrl** key or vertical arrows of left or right image for Y-parallax removal.

Use the button to switch to moving marker mode (to turn off stereocomparator mode) or **Ctrl+F6** hot keys. For tie points measurement in this mode use the following tricks for parallaxes removal:
– rotate mouse wheel along with pressed Ctrl key to change marker’s parallax
– rotate mouse wheel along with pressed Shift key to change horizontal parallax
– rotate mouse wheel along with pressed Ctrl+Shift keys to change vertical parallax

To measure points use the buttons and and keep under control Y-parallax value.

You can use correlation procedure (by pushing the button in the main toolbar of Points measurement window) for automatic point positioning on the right image relatively to its current position on the left image.

You can use additional hot keys during stereo measurements:

F2 – **Adjust depth** – tunes stereo image in such a way that marker will be located on the screen surface (will have zero X-parallax);
F3 – **Restore depth** – restores previous value of image depth;
F11 – **Reverse phase** – swaps direct and reverse stereo effect;
F6 – toggle between fixed marker mode and moving marker mode.

4.4.4 Displaying points

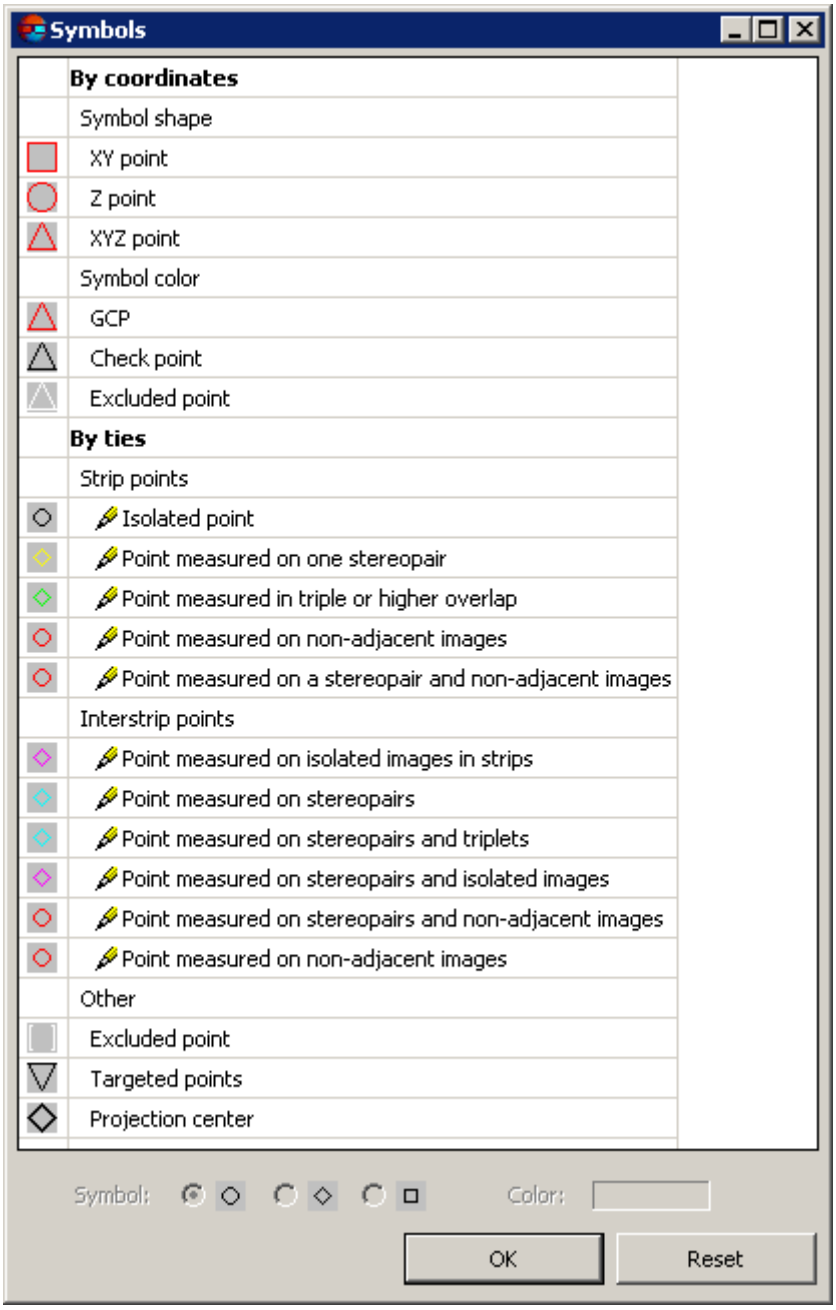
Triangulation points may be displayed in the following windows:

- In the windows of the Points measurement module. The module contains tools for controlling points visualization, including setting up the symbols for different types of points, as well as filter for showing only certain types of points. See also description of tools in chapter Main window of Points measurement module.
- In 2D window over the block layout or a stereopair. Measured points may be loaded in 2D window, with symbol customization and filter available as well. See chapter Displaying points in 2D window.
- On schematic block layout in the **Delete points measurements** window for clearness when deleting points. See chapter Point measurements deletion.

4.4.4.1 *Point symbols*

For customizing point symbols, the button is provided in the Points measurement module for points shown in the module windows, and in the Triangulation points – display options for Displaying points in 2D window over the block layout or a stereopair. Besides that, symbols can be customized in **Delete points measurements** window (see chapter Point measurements deletion). Regardless of where the symbols are set up, the changes made are applied in every window where the triangulation points are displayed.

The **Symbols** ( ) button opens the following window:

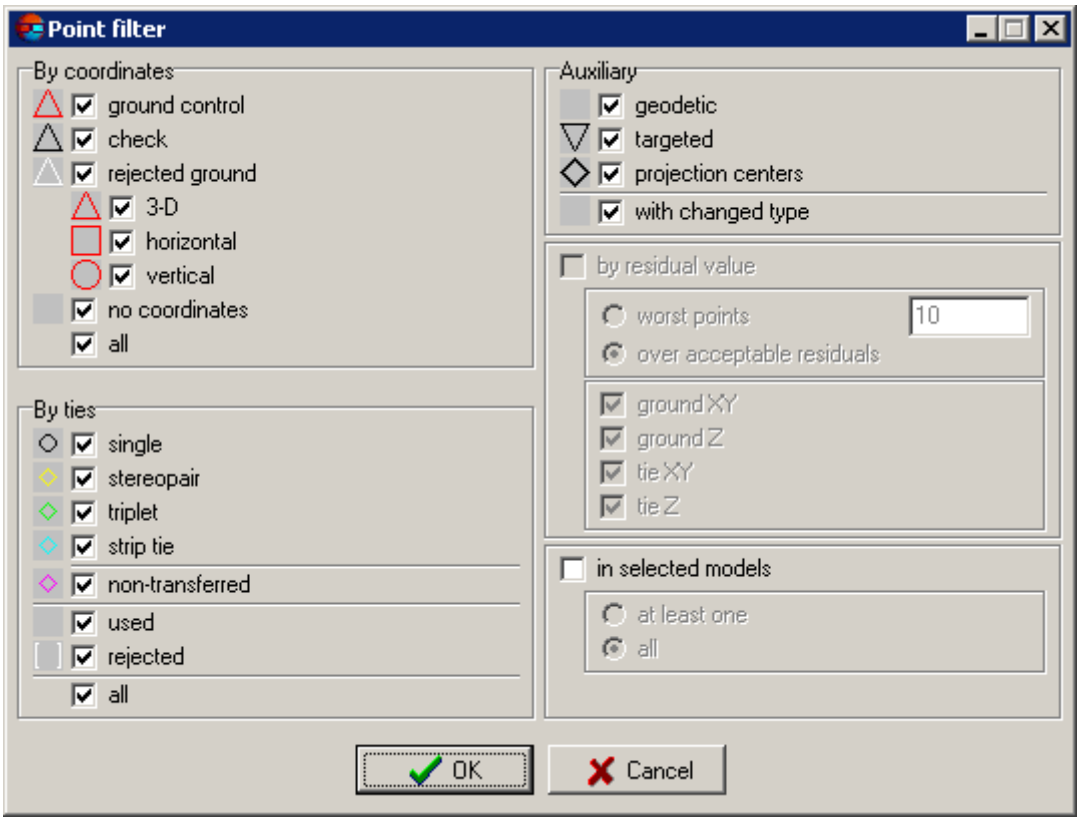


The window contains list of all possible types of triangulation points. The left column shows current symbol for each point type. The pencil icon marks the symbols which can be modified. The symbol modification consists in choosing shape and/or color.
To change a symbol, select the needed point type in the list, choose shape (circle, diamond or square – the **Symbol** field) and setup color, clicking the left mouse button in the **Color** field at the bottom.
To revert settings to defaults, press the **Reset** button (*which becomes available when **Alt** key is held down*).

4.4.4.2 *Point filter*

Apart from customizing point symbols, it is possible applying a filter for displaying only certain types of points. Such filter may be applied to windows of Points measurement module and to 2D windows with block layout or a stereopair (see chapter Displaying points in 2D window).

The filter is activated and deactivated with the button and configured with the button. The latter opens the following window:



Select point types to show

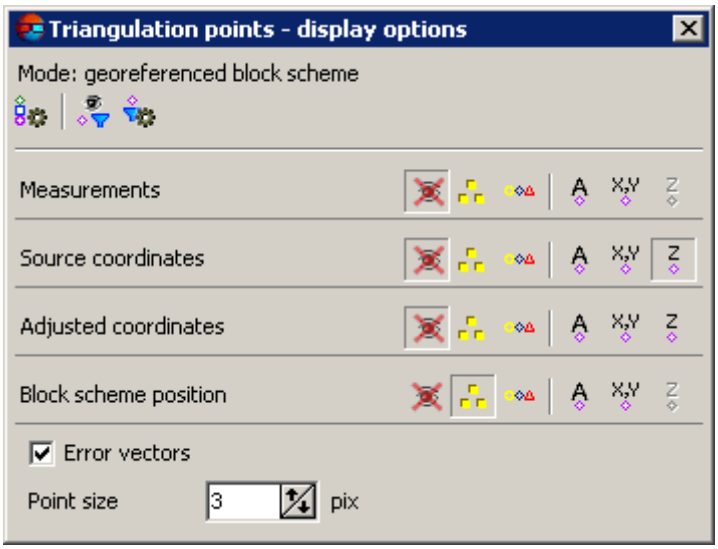
The window sections are used to select points according to the following criteria:

- **By coordinates**
  - **ground control**
  - **check**
  - **rejected ground** - points with known coordinates excluded from adjustment (3D, horizontal and vertical);
  - **no coordinates** – points with coordinates not set (ties).
- **By ties**
  - **single** – measured on one image only (not measured on a stereopair)
  - **stereopair** – measured on at least one stereopair
  - **triplet** – measured on at least one triplet
  - **strip tie** – measured in inter-strip overlap;
  - **non-transferred** – tie points, not measured on neighborhood images;
  - **used** – tie points used in adjustment as ties
  - **rejected** – tie points excluded from adjustment as ties
- **Auxiliary**
  - **geodetic** – tie points, which are not targeted and not projection centers
  - **targeted**
  - **projection centers**
  - **with changed type** – points, type of which has been changed during adjustment
- **In selected models** - only points measured on selected models are shown
  - **at least one** – points belonging to at least one of these models
  - **all** – points belonging to all these models at once
- **By residual value** section is not available, as it relates to adjustment only.

4.4.4.3 *Displaying points in 2D window*

The **Orientation | Load triangulation points** (duplicated by the button on the main **PHOTOMOD Core** toolbar) command is used to display triangulation points in 2D window (on block scheme or on a stereopair). When this command is executed, the following happens:

- a new layer **Triangulation points** is created in the **Layer manager** (this layer is refreshed when the same command is called next time)
- triangulation points are displayed in 2D window
- the **Triangulation points – display options** window is shown (if this window is closed, it can be reopen by menu command **Window | Triangulation points view control**):



All changes made in this window are applied immediately.
The line in the upper part of the window denotes current mode according to the 2D window context (see description of the modes further in this chapter); the toolbar below contains buttons:

- to change symbols (see chapter Point symbols)
- and to toggle and setup the points filter (see chapter Point filter). The filter settings are not saved.
-

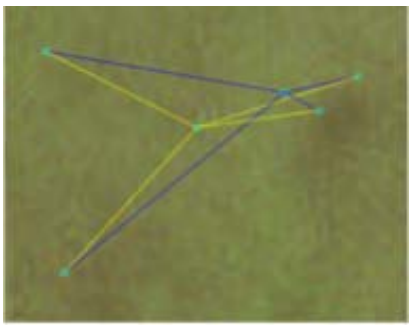
The following point positions can be visualized:

- **Measurements** – point measurements on images
- **Source coordinates** – positions of ground control and check points according to coordinates input in GCP list (see chapter Input and measuring of ground control points)
- **Adjusted coordinates** – positions of all points according to coordinates obtained by block adjustment (see the **Block adjustment** User manual)
- **Block scheme position** – positions of all points computed as arithmetic average of their measurements on images, projected to the block layout coordinates (useful e.g. when the block scheme is not georeferenced). This position type is not available in stereopair 2D window.

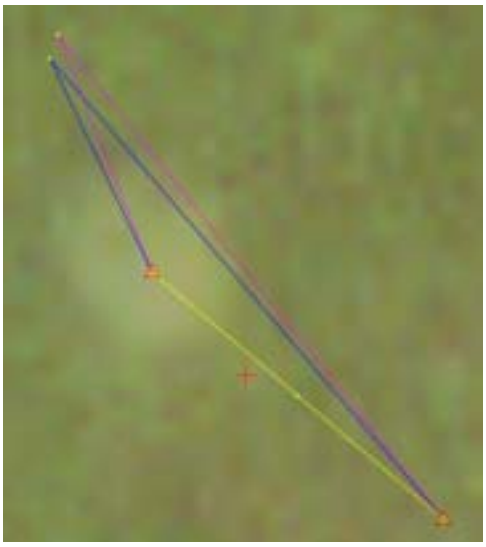
Besides, **Error vectors** connecting the measurements and other types of point positions may be shown, and **Point size** (for points displayed as points, not as symbols) may be adjusted.

Only tie point measurements are shown

Point in adjusted coordinates, as well as error vectors connecting it with its measurements, are shown



Point mean position in block scheme and its error vectors shown



The last example illustrates the GCP measurements on two images, its position in source coordinates and corresponding error vectors (purple), its position in adjusted coordinates and corresponding error vectors (blue), its mean position in block scheme and corresponding error vectors (yellow).

The following tools are available for the point positions:

– do not show – turns the display of corresponding point position

– display as simple points of the given size (the **Point size** field at the bottom of the window)

– display as symbols – display points according to the current symbols setup (the button, see also chapter Point symbols)

– display names – display point name labels (only when the points are also visible)

– show XY coordinates

– show Z coordinates

Current mode indicated at the top of the window, may be one of the following:

- **Georeferenced block scheme** – all point positions can be shown.
- **Non-georeferenced block scheme** – point positions in source and adjusted coordinates (and corresponding error vectors) are not available, only measurements and mean position on block scheme are shown.

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- **Stereopair** – only measurements on left and right images of the stereopair, as well as positions in source and adjusted coordinates are shown; mean position in block scheme is not available.

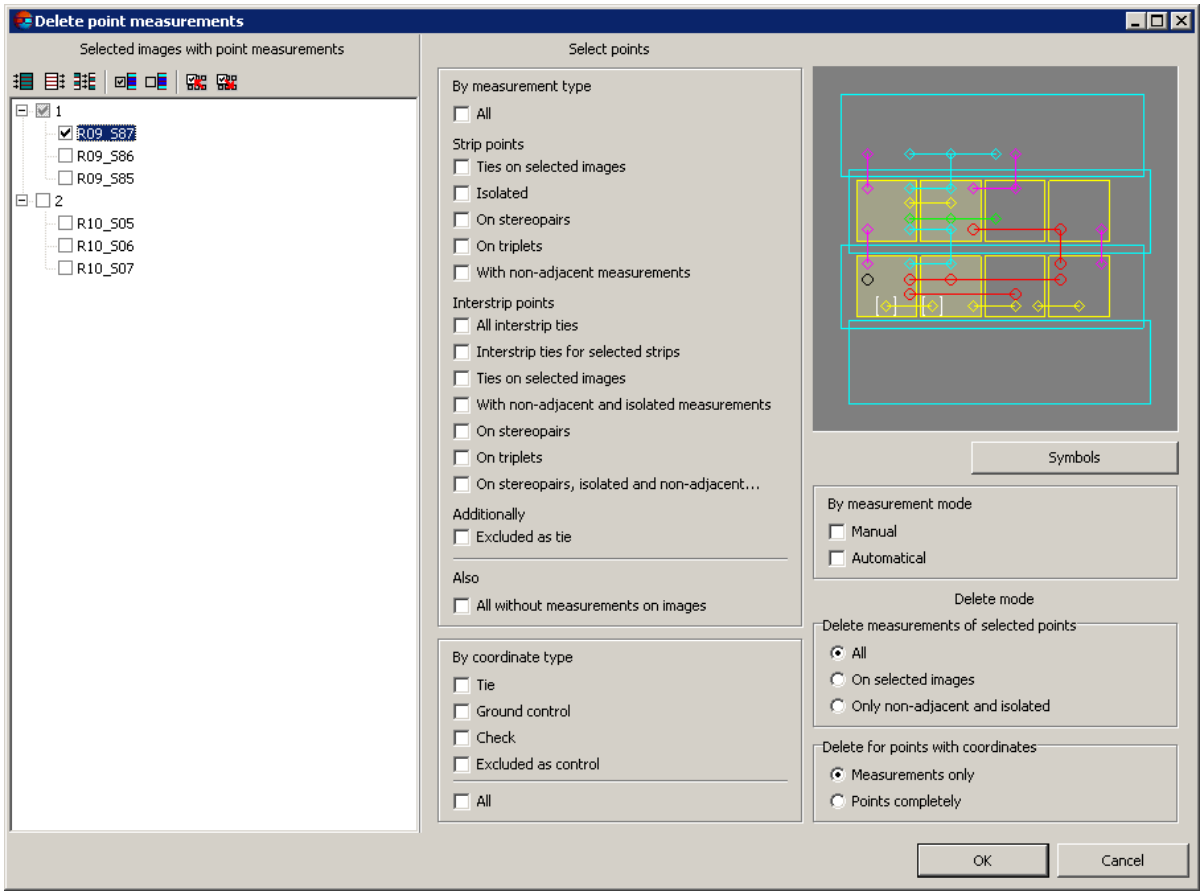
In stereopair mode, "arrows" are shown in addition to a point symbol indicating the ties with neighborhood images.
In modes 1 and 2 the source coordinates display vertical and planimetric-vertical control and check points, in the mode 3 only planimetric-vertical points are displayed.

Besides, a vector layer can be created from triangulation points by carrying out the **Vectors | Create layer from triangulation points** command, so that the points can be used e.g. for TIN creation along with other vector layers. See the **Project processing** User manual.

4.4.5 Point measurements deletion

Apart from the points deleting tools in the **Points measurement** module (see chapter Main window of Points measurement module) and triangulation points lists (see chapter Triangulation points window) the following menu commands are provided:

- **Orientation | Clear point catalogue** – for deleting all points and their measurements (ground control, check and tie);
- **Orientation | Delete point measurements** (duplicated by the button in **AT** toolbar and the Points measurement module toolbar) – for deleting points according to certain criteria. It opens the **Delete point measurements** window:



Selecting point types to delete

The left pane contains the list of project images with standard tools for selecting images.
The right pane represents a comfortable interface for choosing point types to be deleted, and contains a list of options and a graphical scheme illustrating the selected options. The list

and the scheme are synchronized. I.e. when point types are checked in the list, they are highlighted in the scheme, and vice versa, points selected in the scheme are automatically checked in the list. To select several options in the scheme, use the **Shift** key. The **Symbols** button opens the window for setting up the triangulation point symbols. See chapter Point symbols. Apart from that, the graphical scheme supports zooming, panning and brightness-contrast-gamma adjustment (panel activated by **Shift-F8**) in the same way as any 2D window in PHOTOMOD.

Prerequisites for deleting points:

1. At least one points type must be checked in each of the 3 sections:
   - **By measurement type**
   - **By coordinate type**
   - **By measurement mode**
2. At least one image must be selected

Exception – the **All without measurements on images** option (which requires neither a checked option in **By measurement type** section nor selected images), because it defines points not measured on any of the block images (such points may appear e.g. after importing triangulation points).

The following point types may be selected for deleting:

By measurement type (point type is determined by the entire block, not by selected images):

- **All** – points of any type on selected images according to the coordinate type, measurement mode and delete mode.

- **Strip points**
  - **Ties on selected images** – in-strip tie points on selected images (i.e. having two or more measurements on selected images inside a strip)
  - **Isolated** – points having only one measurement among selected images
  - **On stereopairs** – stereopair tie points, including those having non-adjacent measurements inside a strip
  - **On triplets** – all triplet tie points, including those having non-adjacent measurements inside a strip
  - **With non-adjacent measurements** – in-strip tie points having at least one non-adjacent measurement

- **Interstrip points**
  - **All interstrip ties** – all interstrip tie points having *at least one* measurement among selected images
  - **Interstrip ties for selected strips** – interstrip tie points having *strictly all* measurements on selected images
  - **Ties on selected images** – interstrip tie points having two or more measurements on selected images
  - **With non-adjacent and isolated measurements** – interstrip tie points having no stereopair measurements
  - **On stereopairs** – interstrip tie points having stereopair measurements, but having no triplet, isolated or non-adjacent measurements
  - **On triplets** – interstrip tie points, having triplet measurements, but having no isolated or non-adjacent measurements
  - **On stereopairs, isolated and non-adjacent** – interstrip tie points having either stereopair and isolated or stereopair and non-adjacent measurements

- **Additionally**
  - **Excluded as tie** – all tie points on selected images excluded by tie in the Triangulation points window

- **Also**
  - **All without measurements on images** – delete measurements of ground control points not falling on any image of the block (such measurements may appear e.g. after deleting images from the block)

By coordinate type
- **Tie** – only measurements of tie points satisfying other criteria on selected images
- **Ground control** – only measurements of ground control points satisfying other criteria on selected images
- **Check** – only measurements of check points satisfying other criteria on selected images
- **Excluded as control** – only points excluded as ground control (in the Triangulation points window) on selected images
- **All** – all points (except for excluded as ties) satisfying other criteria on selected images

By measurement type
- **Manual** – points measured manually in the Points measurement module (see chapter Manual measuring of triangulation points)
- **Automatical** – point measured automatically (see chapter Automatic tie points measurement).

The deleting mode is set in the corresponding section:
- **Delete measurements of selected points**
  - **All** – delete all *measurements* of selected points, if *at least one* measurement falls on selected images. In this case all measurements of selected points on graphic scheme are marked with red cross
  - **On selected images** – delete measurements of selected points *only* on selected images. At that, if there is only one measurement left outside selected images, it is deleted also. Such isolated measurements are marked with yellow cross
  - **Only non-adjacent and isolated** – delete non-adjacent and isolated measurements on selected images, including inters-strip, having no "ties" inside a strip
- **Delete points with coordinates**
  - **Measurements only** – only measurements are deleted for any points
  - **Points completely** – measurements and entries in points catalogue (in Triangulation points window) are deleted entirely (for ground control, check and excluded points)

When the **OK** button is pressed, a confirmation message box is shown displaying the number of points to be deleted. Press the **Yes** button in this message box to execute the deletion, **No** – to return to the window, **Cancel** – exit without deleting any points. The report is shown after the deletion operation finishes.

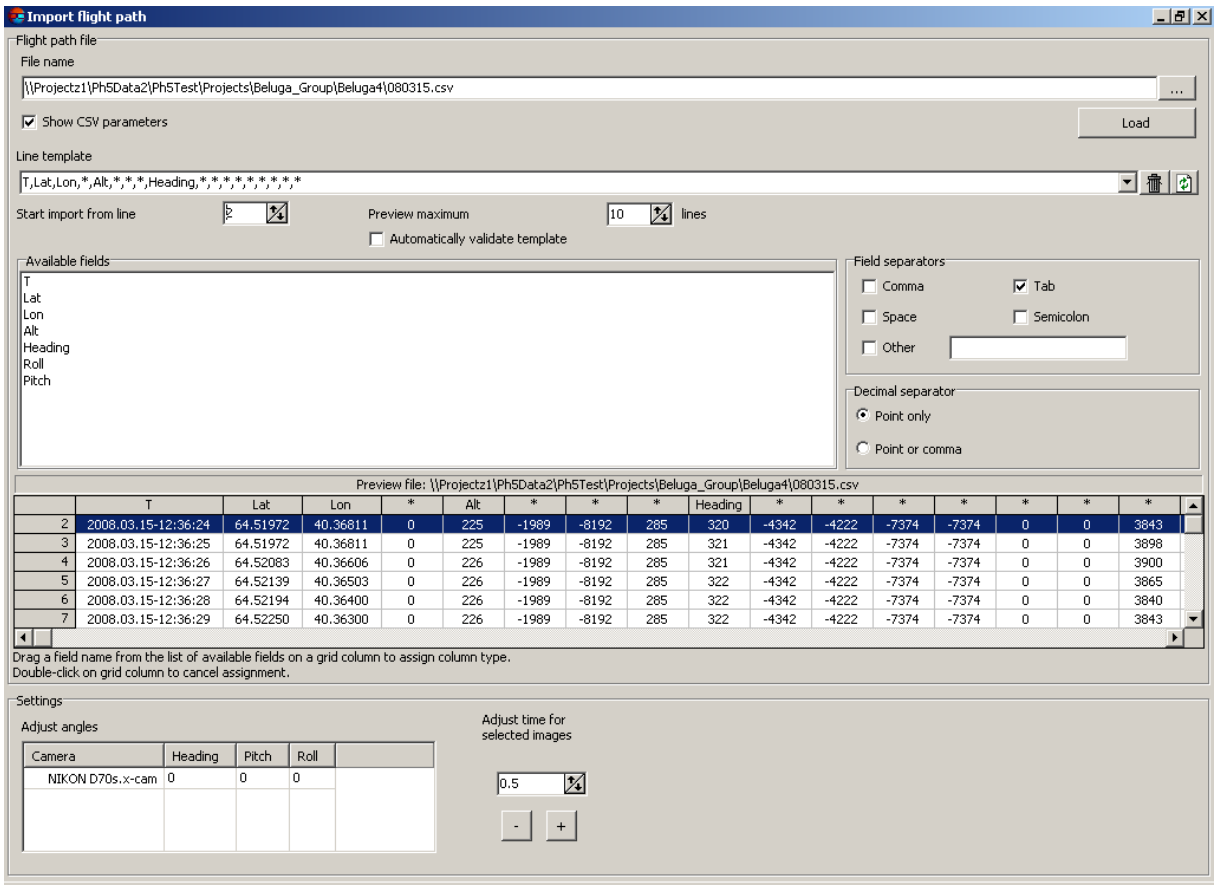
4.4.5.1 *Import of flight line file*

The system provides flight line data import. The data can be used if the time of image acquisition is available, for example, if the orientation data are imported from metadata, exterior orientation data import or GPS data import. So the data for an image are selected using time but not the image number. The time format of the project images must correspond to one of the flight line time.

To import flight line data execute the **Orientation | Import | Import flight line** menu command. The **Import flight path** window will be opened.

Push the ... button to select flight line data CSV file.

Select the **Show CSV parameters** check box to set the flight line file row format.


Import flight path
Flight path file
File name
\\Projectz1\Ph5Data2\Ph5Test\Projects\Beluga_Group\Beluga4\080315.csv
Show CSV parameters
Load
Line template
T,Lat,Lon,*,Alt,*,*,*,Heading,*,*,*,*,*,*,*,*,*
Start import from line
Preview maximum
10
lines
Automatically validate template
Available fields
T
Lat
Lon
Alt
Heading
Roll
Pitch
Field separators
Comma
Tab
Space
Semicolon
Other
Decimal separator
Point only
Point or comma
Preview file: \\Projectz1\Ph5Data2\Ph5Test\Projects\Beluga_Group\Beluga4\080315.csv
T Lat Lon * Alt * * * Heading * * * * * * *
2 2008.03.15-12:36:24 64.51972 40.36811 0 225 -1989 -8192 285 320 -4342 -4222 -7374 -7374 0 0 3843
3 2008.03.15-12:36:25 64.51972 40.36811 0 225 -1989 -8192 285 321 -4342 -4222 -7374 -7374 0 0 3898
4 2008.03.15-12:36:26 64.52083 40.36606 0 226 -1989 -8192 285 321 -4342 -4222 -7374 -7374 0 0 3900
5 2008.03.15-12:36:27 64.52139 40.36503 0 226 -1989 -8192 285 322 -4342 -4222 -7374 -7374 0 0 3865
6 2008.03.15-12:36:28 64.52194 40.36400 0 226 -1989 -8192 285 322 -4342 -4222 -7374 -7374 0 0 3840
7 2008.03.15-12:36:29 64.52250 40.36300 0 226 -1989 -8192 285 322 -4342 -4222 -7374 -7374 0 0 3843
Drag a field name from the list of available fields on a grid column to assign column type.
Double-click on grid column to cancel assignment.
Settings
Adjust angles
Camera Heading Pitch Roll
NIKON D70s.x-cam 0 0 0
Adjust time for selected images
0.5
-
+

Flight line file import

The **Preview file** table displays data from the file being imported arranged in columns. The system tries to determine the column's types according to the template used in last flight line import procedure.

To display the current template which corresponds to the table data push the button (**Validate template**). The column's types and number will be defined only for the rows displayed in the table. The template field number will be equal to the maximum columns number in the table rows displayed.

The following fields are used in the template:
T – GPS-time;
Lat –latitude;
Lon –longitude;
Alt – altitude;
Heading – heading angle;
Roll – roll angle;
Pitch – pitch angle.

The symbol * is used to mark the columns containing data not to be imported.

To change the current template perform one of the following actions:
- Using mouse, drag the field name from the **Available fields** list onto the table column to define the column type. The template in the **Line template** input field will be automatically changed. Double-click on the table columns cancels the field selection.

- Change the template manually in the **Line template** input field. The table column's types are changed automatically.

The **Automatic validate template** checkbox provides automatic selection of the current template on pressing the **Load** button. So it is enough to define the table's to be imported columns types, to set the **Automatic validate template** checkbox and push the **Load** button. If the file contains rows with different columns number, unselect the **Automatic validate template** checkbox and set the template manually in the **Line template** input field.

To define the file rows number to display in the table set it in the **Preview maximum lines** input field. To define the row number to start the data import set it's number in the **Start import from line** filed.

In the appropriate window sections set the file columns delimiter's type (**Comma**, **Space**, **Tab**, **Semicolon** or **Other** delimiters) and decimal delimiter for the coordinates values in the file (**Point only**, **Point or comma**)

It's possible to set angles refinements from the camera calibration data in the **Settings** section.

To import flight line data press the **Load** button. The **Import flight path** window will not close. The data imported are displayed in the Exterior orientation data list. Refresh the block layout – push the **By exter. or.** button in the **Block layout** window (see the chapter Block layout).

Note: To create correct block layout the elevation range data are necessary, which are specified in the project properties or during exterior orientation data import.

After block layout creating the time refinements to the images selected can be introduced. Use the

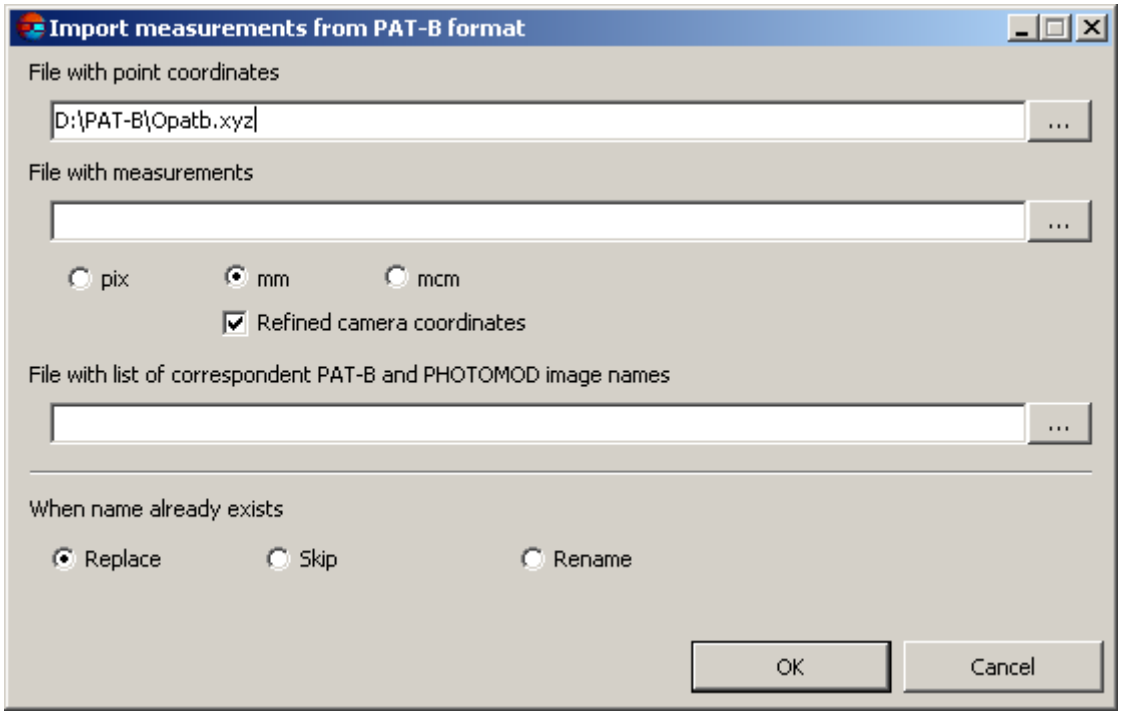
and

buttons for time arrangement along the flight line according to value in the **Adjust time for selected images** field.

4.4.6 Triangulation points import

4.4.6.1 *Import from PAT-B*

For import of GCP and tie points measurements from PAT-B format use menu command **Orientation | Import | Import tie points from PAT-B** or corresponding command from drop-down menu of the button in Triangulation points window. After that the **Import measurements from PAT-B format** window is opened.

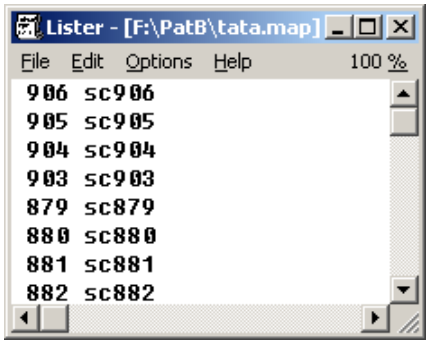


Import measurements from PAT-B format

Select **File with points coordinates** with (*.xyz, *.txt, *.csv) extension, format description see in the chapter Format of file of geodetic point's coordinates.

Then select **File with measurements** with (*.mea, *.txt, *.csv) extension. Define measurement units used in image coordinate system (pixels, mm or micron). If the coordinates are corrected for distortion and principal point offset you should select the option **Refined camera coordinates**. Format description see in the chapter Format of file of points measurements on images.

If necessary select file that matches images names in PAT-B and **PHOTOMOD**. This file stores images names (numbers) from selected files that contain geodetic coordinates of points and points measurements, and also corresponding names of images in **PHOTOMOD** system.



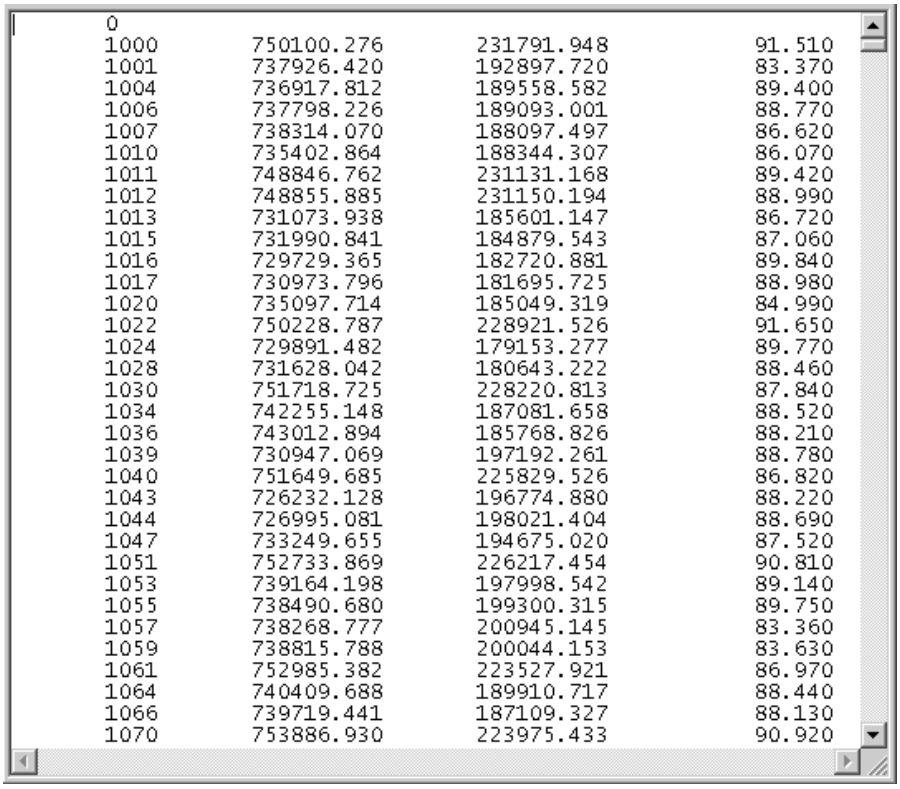
Sample of images numbers and names matching file

Specify action if imported triangulation points names coincide with points names already existing in a project – replace, skip or rename.

Click **OK**. Imported points will be added to triangulation points list.

4.4.6.1.1 Format of file of geodetic point's coordinates

The first column of **file with points geodetic coordinates** contains ground control point number and other 3 columns contain X, Y, Z coordinates of the point respectively. Space or several spaces are used as a delimiter.



```
0
1000        750100.276        231791.948        91.510
1001        737926.420        192897.720        83.370
1004        736917.812        189558.582        89.400
1006        737798.226        189093.001        88.770
1007        738314.070        188097.497        86.620
1010        735402.864        188344.307        86.070
1011        748846.762        231131.168        89.420
1012        748855.885        231150.194        88.990
1013        731073.938        185601.147        86.720
1015        731990.841        184879.543        87.060
1016        729729.365        182720.881        89.840
1017        730973.796        181695.725        88.980
1020        735097.714        185049.319        84.990
1022        750228.787        228921.526        91.650
1024        729891.482        179153.277        89.770
1028        731628.042        180643.222        88.460
1030        751718.725        228220.813        87.840
1034        742255.148        187081.658        88.520
1036        743012.894        185768.826        88.210
1039        730947.069        197192.261        88.780
1040        751649.685        225829.526        86.820
1043        726232.128        196774.880        88.220
1044        726995.081        198021.404        88.690
1047        733249.655        194675.020        87.520
1051        752733.869        226217.454        90.810
1053        739164.198        197998.542        89.140
1055        738490.680        199300.315        89.750
1057        738268.777        200945.145        83.360
1059        738815.788        200044.153        83.630
1061        752985.382        223527.921        86.970
1064        740409.688        189910.717        88.440
1066        739719.441        187109.327        88.130
1070        753886.930        223975.433        90.920
```

Sample of file with adjusted geodetic coordinates of points in PAT-B format

4.4.6.1.2 Format of file of points measurements on images

File with points measurements on images is divided into sections corresponding to each image. The section is started from an image number which is followed by focal length value and “0” value. Then you can see lines consisting of point name (number), its X and Y coordinates relatively to the principal point in mm or microns. It is also possible to specify X, Y coordinates relatively to the principal point in mm or microns or in pixels on image. One or several space characters are used as fields delimiter. The section is ended with “-99” value.

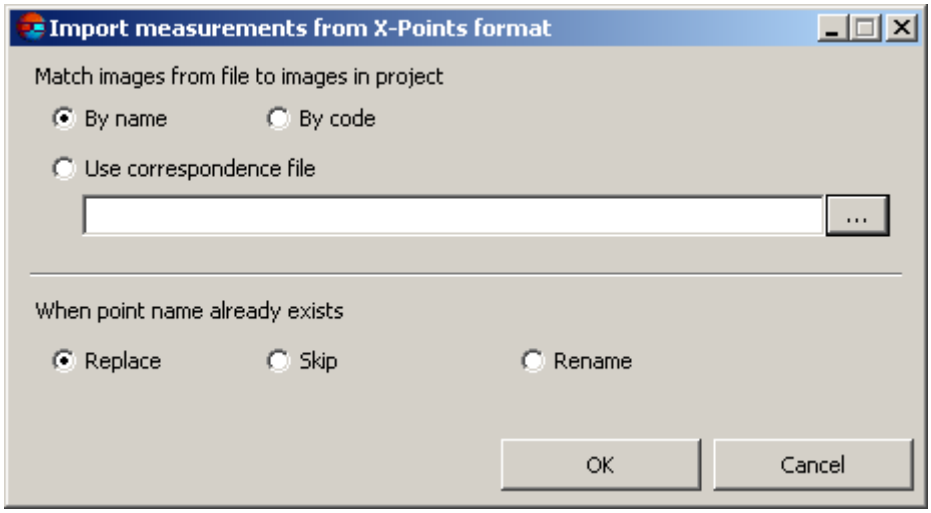
```
                    R09_S87     153406.0 0
                       0556     -94575.2      73257.1
                       0911     -28662.7      76350.2
                        *12      -8748.1     -54028.7
                        *13     -89762.6     -19562.2
                        *15     -55554.4    -102344.2
                        *16      76163.4      11952.5
                        *18      -7686.1     -51046.6
                        *20      35020.3     -62369.1
                        *26      -5454.7     -69827.9
                        *27      88731.6      30981.7
                        *28     -11151.3      19986.7
                        *29      10400.8      22578.4
                        *30      96327.1     -66900.9
                        *31      99825.6      87397.2
                        *32      -8023.0      99370.8
                        *33      79962.0      63612.0
                        *35     -16869.1      96717.5
-99
                    R09_S86     153406.0 0
                       0911     -95919.9      58400.6
                       0908     -14496.2      90413.8
                       0904      47960.2     -76357.2
                        *12     -86365.9     -73273.9
                        *16       4603.4     -10688.4
                        *17     -53629.9      -5952.0
                        *18     -84869.3     -70194.2
                        *19      88133.2     -16205.9
                        *20     -41678.9     -85134.0
                        *21      -6980.8     -47309.0
                        *24      69950.2      -7814.9
                        *26     -84487.6     -90262.6
                        *27      18174.2       7688.0
                        *28     -83022.1       2575.9
```

Sample of points measurements file in PAT-B format

4.4.6.2 *Import from X-Points*

X-Points format is a format of **PHOTOMOD 5.0** system. For import of GCP and tie points measurements from X-Points, use menu command **Orientation | Import | Import tie points from X-Points** or corresponding command from drop-down menu of the button in Triangulation points window. In the window opened browse for file containing triangulation points (with **x-points** extension) and click **Open**. The window **Import measurements from X-Points format** with operation parameters appears.

Define a rule of matching images names in x-points-file with images names in a project: select matching by names, by codes or use file of correspondence.



Specify an action to be performed, if imported triangulation points names coincide with points names already existing in a project – replace, skip or rename.

Click **OK**. Imported points will be added to triangulation points list.

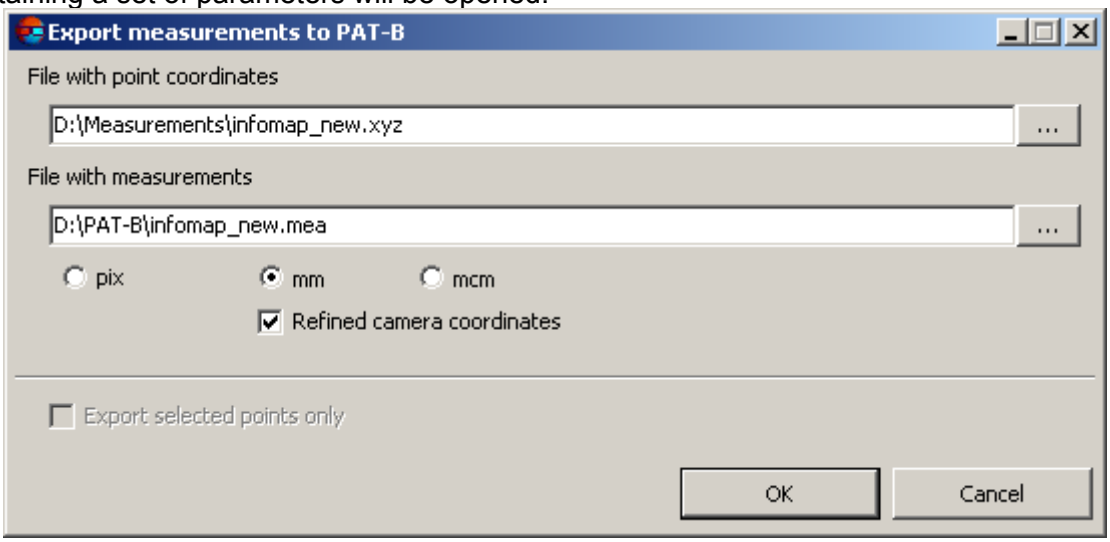
4.4.6.3 *Triangulation points import from PHOTOMOD 4.x XPT*

To import triangulation points catalog from **PHOTOMOD 4.x** project execute menu command **Orientation |Import |Import tie points from PHOTOMOD 4.x XPT**. XPT-file selection window will open (the file should be before head created using **PHOTOMOD 4.x** points catalog export to xpt command). Select file and press **OK**. The imported points will be added to triangulation points list.

4.4.7 Triangulation points export

4.4.7.1 *Export to PAT-B*

For export triangulation points measurements to PAT-B format use menu command **Orientation | Export | Export tie points to PAT-B**, or corresponding command from drop-down menu of the button in Triangulation points window. In the window opened specify a folder and a file name containing geodetic coordinates with **.xyz** extension (see also the chapter Format of file of geodetic point's coordinates) and click **Save**. The project name will be offered as a file name by default. The window **Export measurements to PAT-B** containing a set of parameters will be opened.



Export to PAT-B

As a result files with extensions **.mea** and **.xyz** are created in the selected folder, which are analogous to those described in the chapter 11.1.3 Import of points measurements.

Points measurements (in **mea**-file) are saved be default in the same folder as file with geodetic coordinates. Format description see in the chapter Format of file of points measurements on images.

Define measurement units used in image coordinate system (pixels, mm or micron). If the coordinates are corrected for distortion and principal point offset you should select the option **Refined camera coordinates**.

Check the **Export selected points only** box, if you would like to export just points selected *in the list* (see the chapter Triangulation points window).

4.4.7.2 *Export to X-Points*

For export of GCP and tie points measurements to X-Points use menu command **Orientation | Export | Export tie points to X-Points**. In the window opened specify a folder and a target file name (with **x-points** extension) and click **Save**. All triangulation points of a project will be exported to specified location.

Besides, for export of project triangulation points to X-Points you can use corresponding command from drop-down menu of the button in Triangulation points window. In this case you can perform export either of all points or just those selected in the list.

4.5 *Relative orientation accuracy control*

After completing of images relative orientation you can view its results, perform analysis and accuracy control of the operation, executed in automatic or in manual mode (see the chapter Automatic tie points measurement and Manual measuring of triangulation points) using **Report on relative orientation**.
The report is created considering control parameters and acceptable residuals, specified in the window of Relative orientation report settings.

Relative orientation and accuracy control includes:

- accuracy control for measurements on stereopairs using residual vertical parallaxes
- accuracy control for measurements in triple overlap zones using discrepancies in tie points measurements taken on two adjacent stereopairs (models)
- control of points number and uniformity of their distribution on stereopairs and in triplets
- control of difference between kappa angle and block scheme

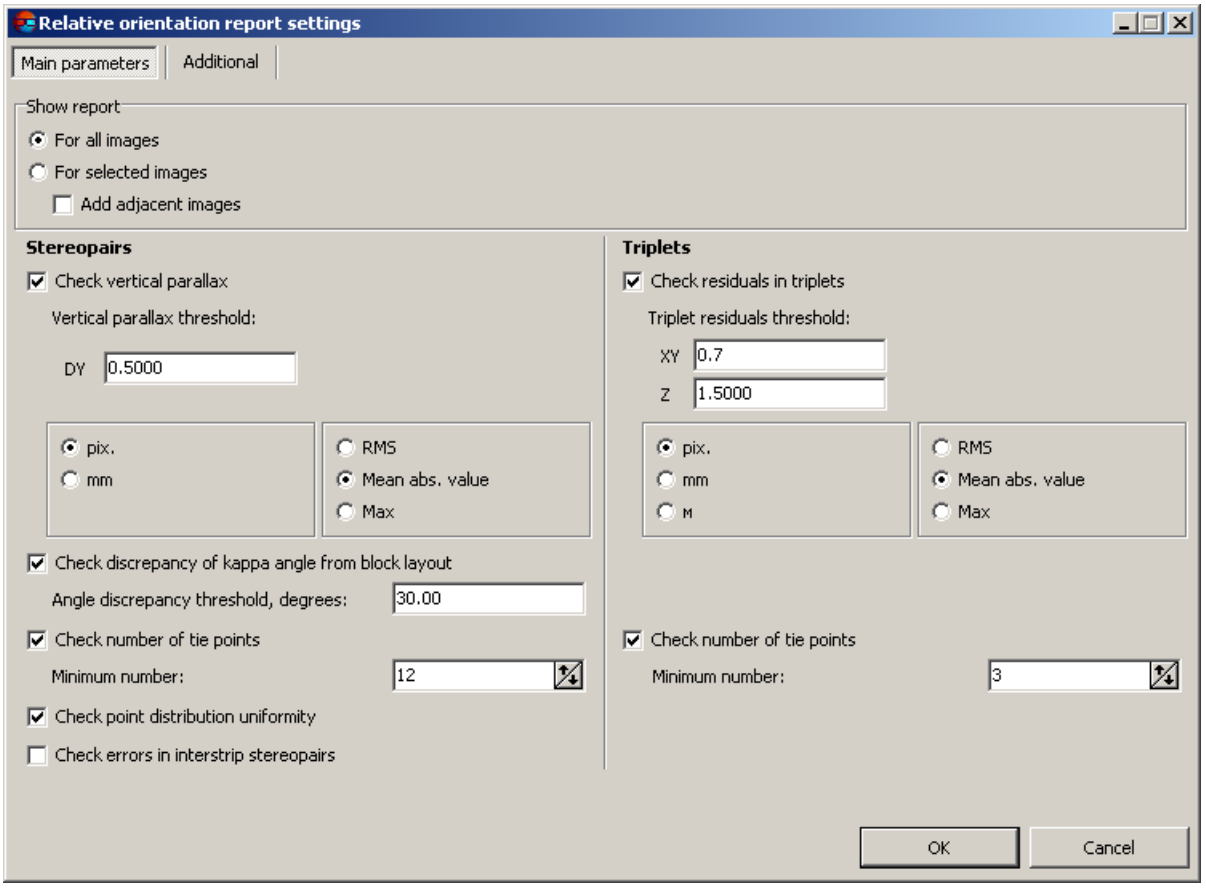
Use menu command **Orientation | Report on relative orientation** (duplicated by the button) to open a report. In this case, prior to report opening the **Relative orientation report settings** window is opened.

You can open the report from other windows using the button or automatically after performing of relative orientation in Automatic tie points measurement window or in Points measurement module. In these cases, the report is opened immediately, and you should remember that it is created considering report parameters specified by default or pre-set in the **Relative orientation report settings** window. You can easily view and edit if necessary the report parameters directly from report (by clicking the **Report parameters** link).

See the chapter Relative orientation report settings and Relative orientation report.

4.5.1 Relative orientation report settings

The **Relative orientation report settings** window allows to specify parameters for relative orientation accuracy control, and setup a format of report output data.



Relative orientation report parameters

The window consists of two tabs – **Main parameters** and **Additional**.

Main report parameters

The **Show report** section allows to define images, which will be analyzed for the report: all images of a block or selected images with addition of adjacent ones if necessary.

To check measurements for vertical parallax error select the **Check vertical parallax** option and input acceptable threshold value (in pixels or mm) for selected error type (RMS, mean or maximal error). It is recommended to reject points with vertical parallax which exceeds image pixel size.

To perform accuracy control of measurements in triplets select the **Check residuals in triplets** option and input acceptable threshold value in XY and Z (in pixels, mm or meters) for selected error type. Acceptable residual for maximal error in triplets could be calculated using the following formula:

$E_{\max} \approx 2 \cdot E_{mean}$, where E_{mean} - mean error

Mean triplet errors in XY plane should not be greater than half of pixel size multiplied by $\sqrt{2}$, error by Z equals the mean triplet errors value in XY plane multiplied by the ratio of focal length (f) to survey basis (b) (in image scale). See below:

$$E_{mean}^{xy} = \sqrt{2} \cdot 0.5\, pxl$$

$$E_{mean}^{z} = \frac{f}{b} \cdot E_{mean}^{xy}$$

If it is necessary, you can check a discrepancy of kappa angle with block scheme. To do that, select the **Check discrepancy of kappa angle from block layout** checkbox and specify angle discrepancy threshold in degrees. It is recommended to setup the value within 30 and 45 degrees.

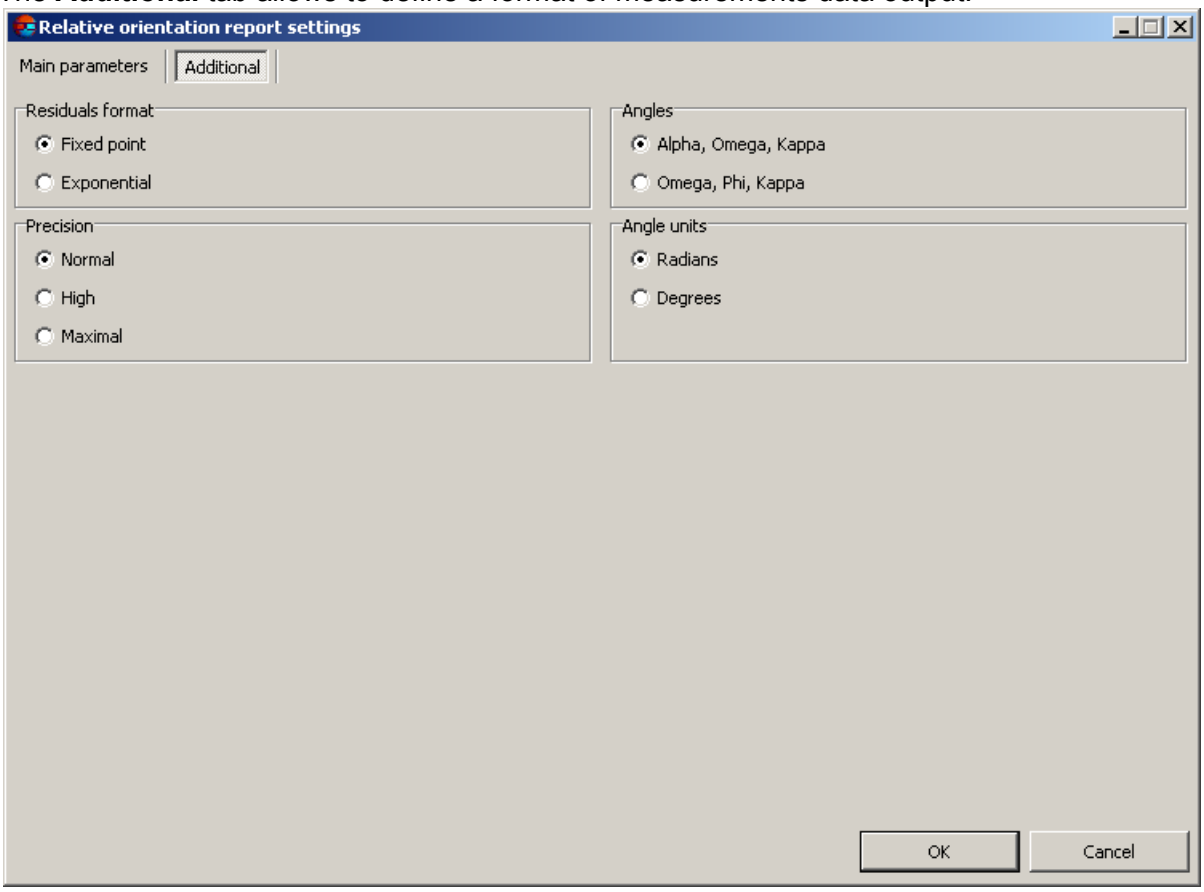
Moreover, you can check a number of measured tie points on stereopairs and in triplets. It is recommended to have at least 12 points for stereopair inside a strip (2 points per each of 6 standard zones, see the chapter Relative orientation), at least 2 points for inter-strip stereopair and at least 3 points for each triplet. Select the appropriate checkbox **Check number of tie points** and setup minimal number of points.

The **Check point distribution uniformity** option is used for control of number and uniformity of distribution of tie points in inter-strip stereopairs. The option is disabled by default, since in most cases analysis of points amount in 6 standard zones for inter-strip stereopair may be redundant.

It is also possible to control uniformity of tie point distribution on stereopairs. *points distribution on a stereopair* is considered *nonuniform*, when in any of 6 equal zones, on which images overlap area is conventionally divided (6 standard zones), points number differs from average points number in zone more than two times less or more. To detect errors select the **Check point distribution uniformity** option.

Additional parameters of report

The **Additional** tab allows to define a format of measurements data output:



Additional parameters of report

Select data output format, define precision, angles system and angles units.

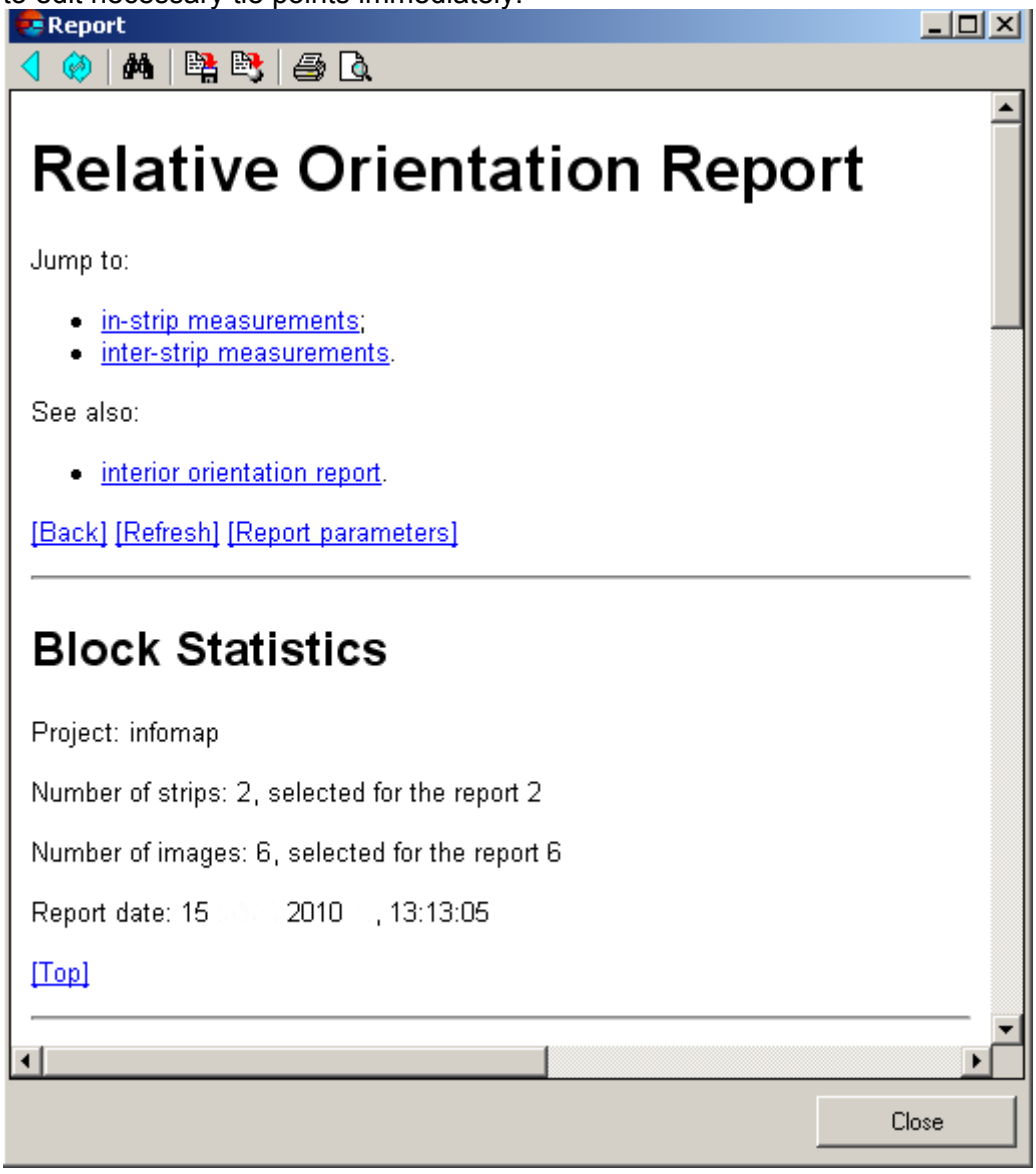
When all parameters are specified, click **OK**. The Relative orientation report window will be opened.

4.5.2 Relative orientation report

Open a report by selecting menu command **Orientation | Report on relative orientation**, that is often duplicated by the button in different windows of **PHOTOMOD Core**.

The report contains results of relative orientation operation and allows to view statistics of tie points measurements, and detect and correct measurements errors. The report is created for selected images considering accuracy control parameters specified in Relative orientation report settings window.

Main feature of the report is a possibility to open **Relative orientation** window directly that allows to edit necessary tie points immediately.



Block statistics section in relative orientation report

Report contains links allowing to pass to specific report sections, to open interior orientation report (see the chapter Report on interior orientation), to return to previous page, as well as to change a report parameters (see also the chapter Relative orientation report settings).

The first page of report displays general info on measurements and contains three main sections:

Block statistics section – general data: project name; total images amount in the project; images amount selected for the report; report creating date.

In-strip measurements section – statistics of tie points measurements inside a strip – in in-strip stereopairs and triplets.

The first *strips table* of a section contains a list of strips and shows:

- number of stereopairs and triplets in each strip (in the **Total** field)
- number of stereopairs and triplets, which contain errors less than specified acceptable threshold (in the **Complete** field)
- number of stereopairs and triplets, which contain errors exceeding specified acceptable threshold (in the **Residuals** field)
- number of stereopairs and triplets, where relative orientation is not completed (in the **Not complete** field)

If relative orientation inside a strip is performed with errors its results are highlighted by yellow. Strips without relative orientation performed are highlighted by red.

Below you can see tables with all stereopairs and triplets for each strip.

A table of strip stereopairs contains a list of stereopairs and statistics of measurements for each stereopair:

- amount of common points on left and right images of a stereopair;
- values of vertical parallax (RMS, maximal or mean absolute value) for all measurements of a stereopair;
- information about non-uniform points distribution in overlap area;
- discrepancy of kappa angle with block scheme.

Yellow color shows stereopairs with measurements errors, red color – stereopairs without relative orientation performed. Additionally, accuracy errors themselves are shown by red color, depending on the following parameters specified in the Relative orientation report settings window:
– number of points measured on a stereopair is less than specified;
– values of vertical parallax that exceed a threshold;
– points distribution non-uniformity;
– discrepancy of kappa angle exceeding the angle specified.

A table of triplets shows a number of measured points in each triplet, triplet errors in XY-plane and in Z, as well as points distribution uniformity.

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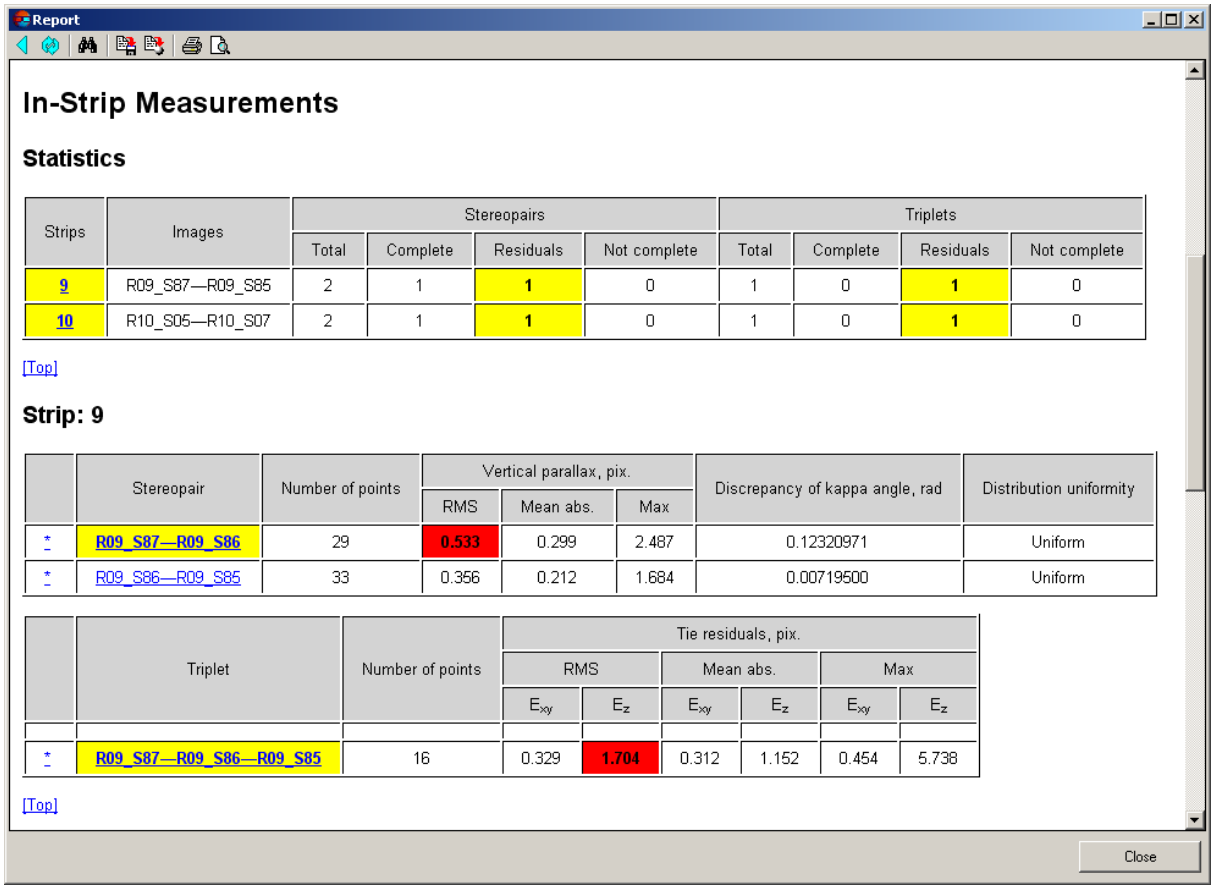
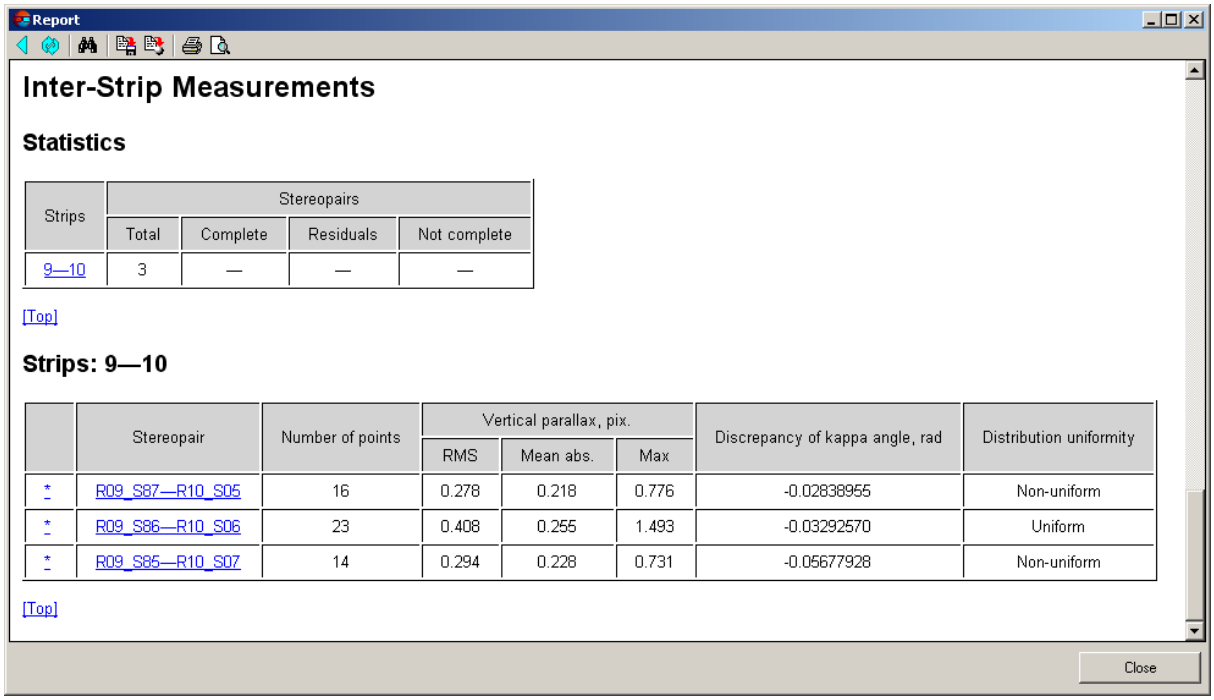


In-strip measurements section

Inter-strip measurements section – statistics of tie measurements points on stereopairs between strips.

A table of inter-strip measurements shows a number of inter-strip stereopairs for each pair of adjacent strips and errors of relative orientation operation.

A table of inter-strip stereopairs shows a number of measured points on each inter-strip stereopair, values of vertical parallax residual, points distribution uniformity and discrepancies of kappa angles with block scheme. The table is similar to the table of in-strip stereopairs.



Inter-strip measurements section

Note. Stereopairs, triplets and strips containing points that exceed the threshold are highlighted by yellow color. Errors values are highlighted by red.

The leftmost column of stereopairs and triplets table contains the * link, which allows to open these stereopairs or triplets in Points measurement module and edit tie points there. After editing and closing of **Points measurement** module you should click the **Refresh** link located in upper part of the report to refresh the relative orientation report. After that the results of relative orientation will be recalculated and new report will be created.

After clicking links of stereopairs and triplets names (numbers) in **Stereopair** column of the report tables, the detailed reports on tie points measurements will be opened. See also the chapter Report for selected stereopair and Report for selected triplet.

4.5.2.1 *Report for selected stereopair*

After clicking on a *stereopair link* in tables on the first page of **Relative orientation report** the detailed report on selected stereopair measurements is opened. The report contains tie points measurements on a stereopair, calculated relative orientation parameters, kappa angles discrepancies and uniformity of tie points distribution in standard zones.

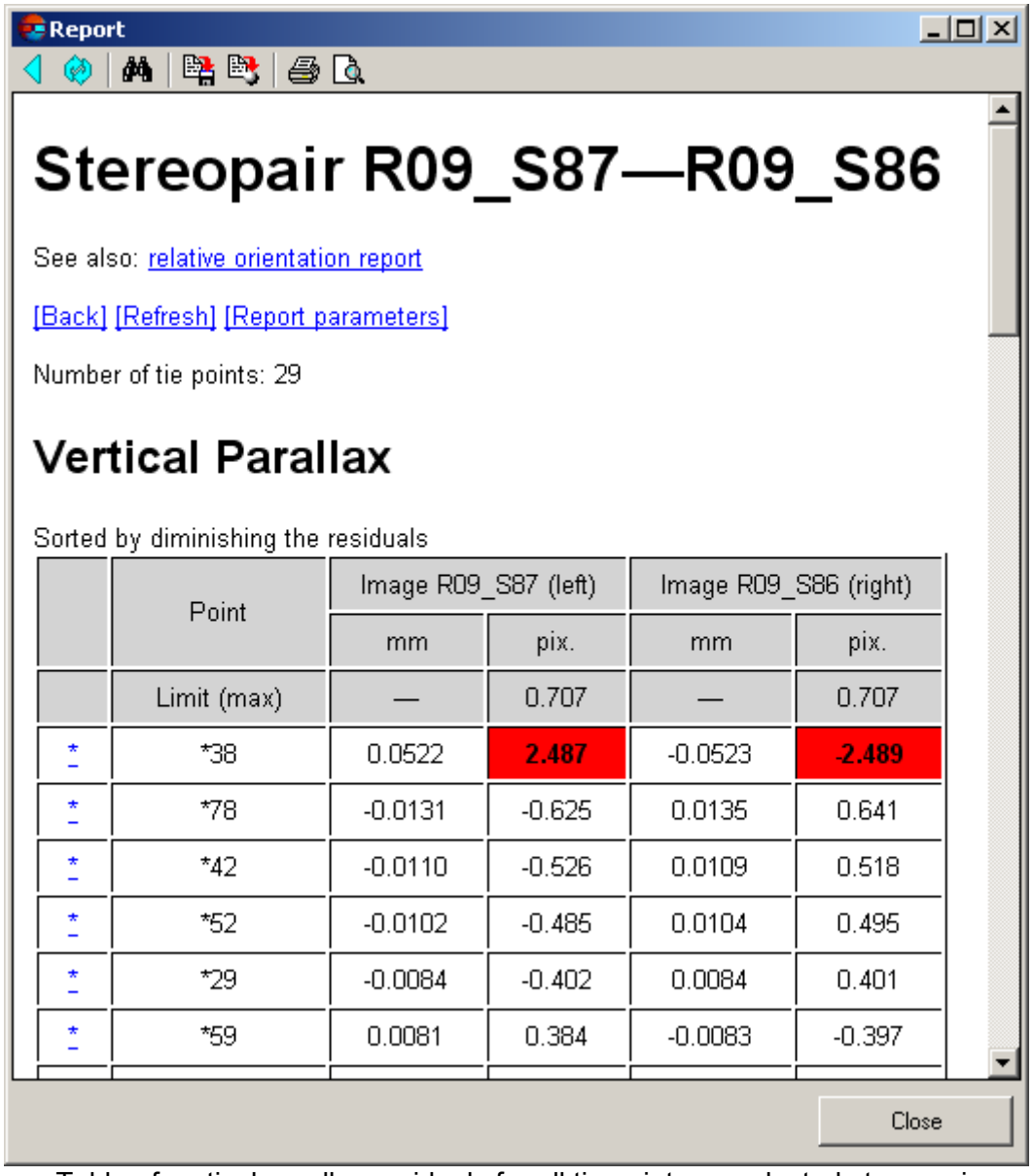


Table of vertical parallax residuals for all tie points on selected stereopair

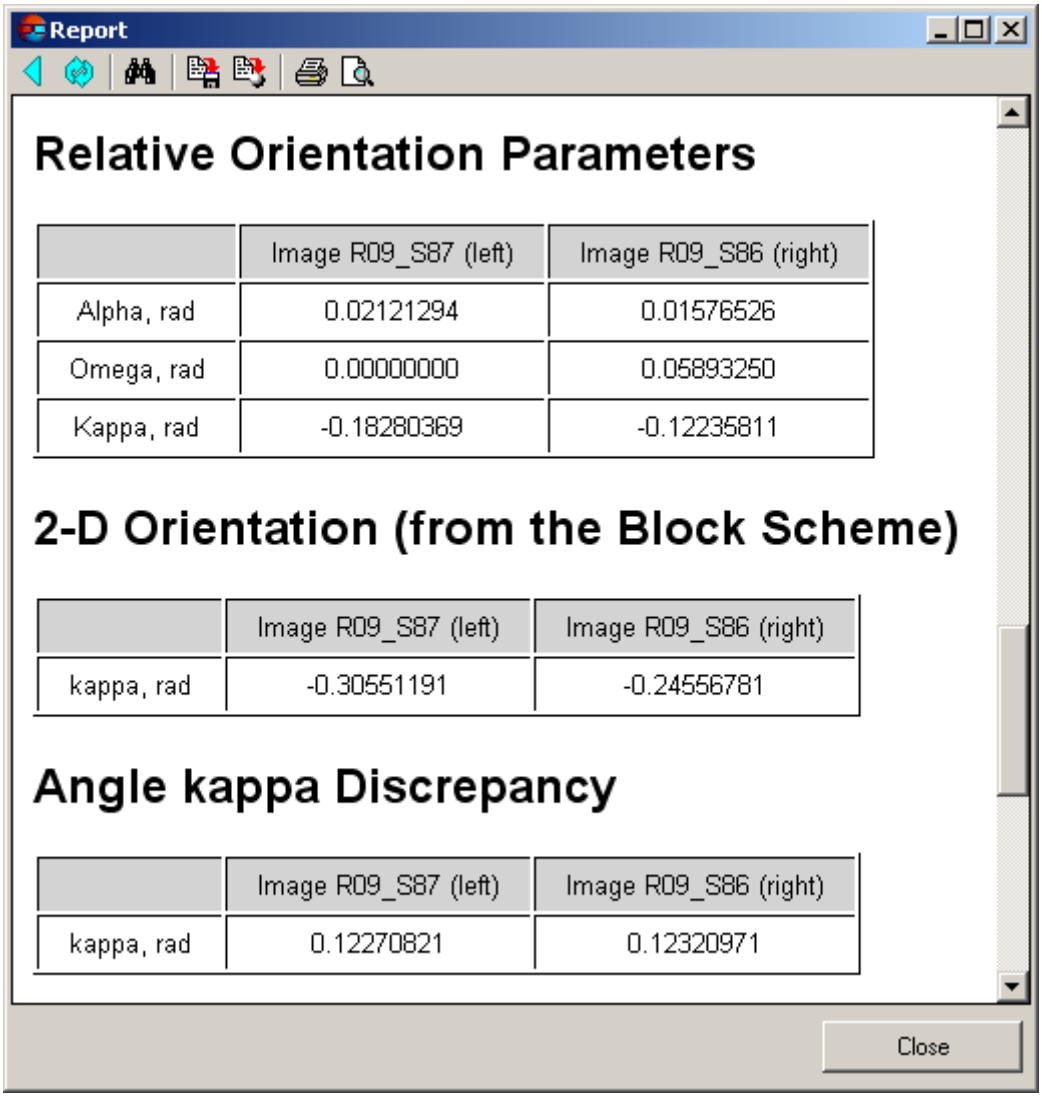
The report allows to control accuracy of measurements of common points of stereopair images by vertical parallax residuals.
Red color shows values of vertical parallax residuals, exceeding a threshold specified in Relative orientation report settings window. Specified threshold is shown in the **Limit (max)** row of points table.

To edit erroneous tie point in Points measurement module click the * link. Selected point is displayed on images of stereopair and highlighted in the list of the module.

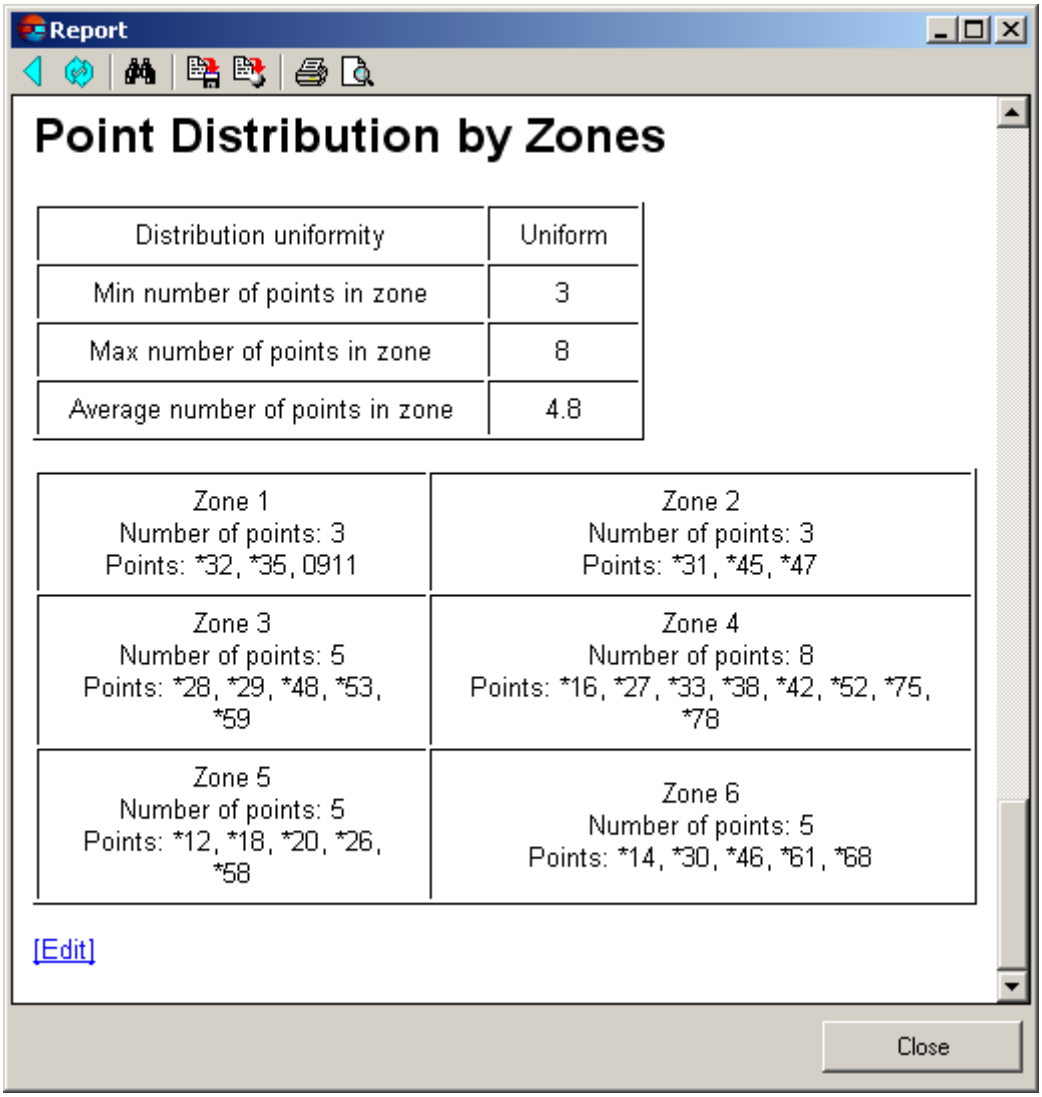
At the bottom of the table you can see total values of vertical parallax residuals (RMS, mean abs. and maximal parallax) for all measurements on a stereopair.

Vertical parallax residual is controlled for the type of error, specified in Relative orientation report settings window.

Further you can see a table with calculated relative orientation parameters (alpha, omega and kappa angles), a table of kappa angles discrepancy, as well as points distribution uniformity by standard zones.



Selected stereopair report. Relative orientation parameters and kappa angle discrepancy



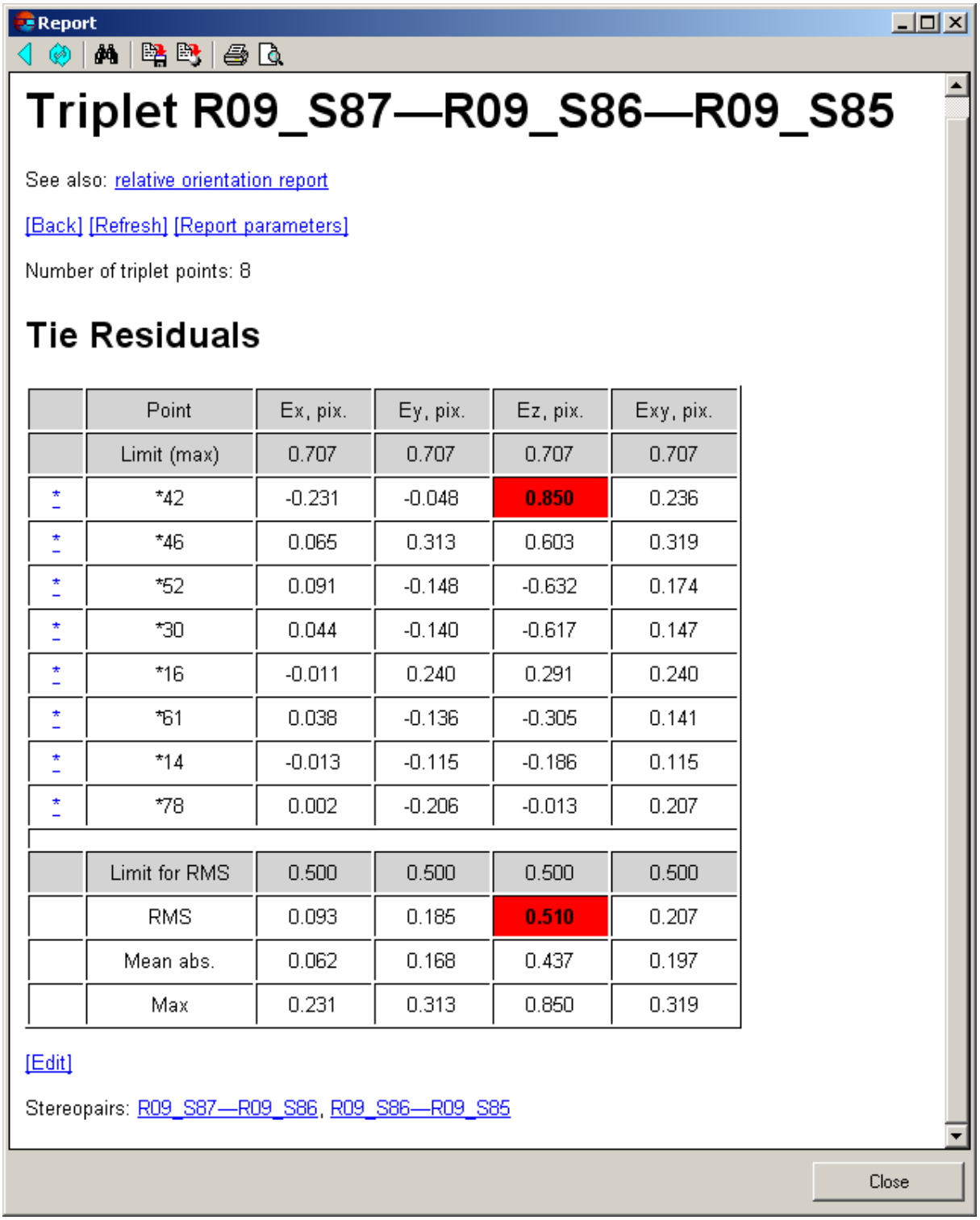
Selected stereopair report. Distribution uniformity data points

To estimate points distribution uniformity the program analyses difference of points amount in each of 6 standard zones.

4.5.2.2 *Report for selected triplet*

After clicking on a *triplet link* in tables on the first page of **Relative orientation report** the detailed report on selected triplet measurements containing a detailed report on measurements data of all triplet points is opened.

The **Tie residuals** table contains triplet errors values in XY and Z for each triplet point.
The **Limit (max)** row displays acceptable thresholds for certain error type, specified in Relative orientation report settings window (RMS, mean abs. or maximal error). Red color shows values of triplet errors, exceeding the threshold.



To edit erroneous triplet point in Points measurement module click the * link. Selected point is displayed on 3 triplet images and highlighted in the list of the module.

At the bottom of the table you can see total values of triplet errors (RMS, mean abs. and maximal) for all measurements on a triplet.

Triplet errors are controlled for the type of error, specified in Relative orientation report settings window.

5. Import of exterior orientation data

Exterior orientation parameters are *coordinates of projection centers* and *three angles* that together define real position of images in space.

If exterior orientation parameters are available with necessary accuracy, you can skip aerial triangulation stage and proceed right away to stereopairs processing – stereo vectorization, DEM building, orthoimage creation (see **Project processing** User Guide). See also the chapter Accuracy control of imported data.

Otherwise, you should perform block measurement and adjustment stages, at that imported exterior orientation parameters could be used for block scheme correction (considered during block layout creation), that would be helpful for GCP/tie points measurement stage. See also the chapter Relative orientation and ground control points measurement.

There are *important conditions* of successful import of exterior orientation parameters:

- correct results of interior orientation;
- defined values of *minimal and maximal terrain heights* (**Zmin**, **Zmax** in meters), which should be specified either on project creation stage (see **Project creation** User Guide) or directly during import of exterior orientation parameters in Import exterior orientation data window.
  Note: If the terrain height difference on images block is more than 1/10 of flight altitude, we recommend to use ground pixel size (GSD) to create block layout by imported data. See the chapter Block layout.

Use the following *operations order* while using exterior orientation parameters:

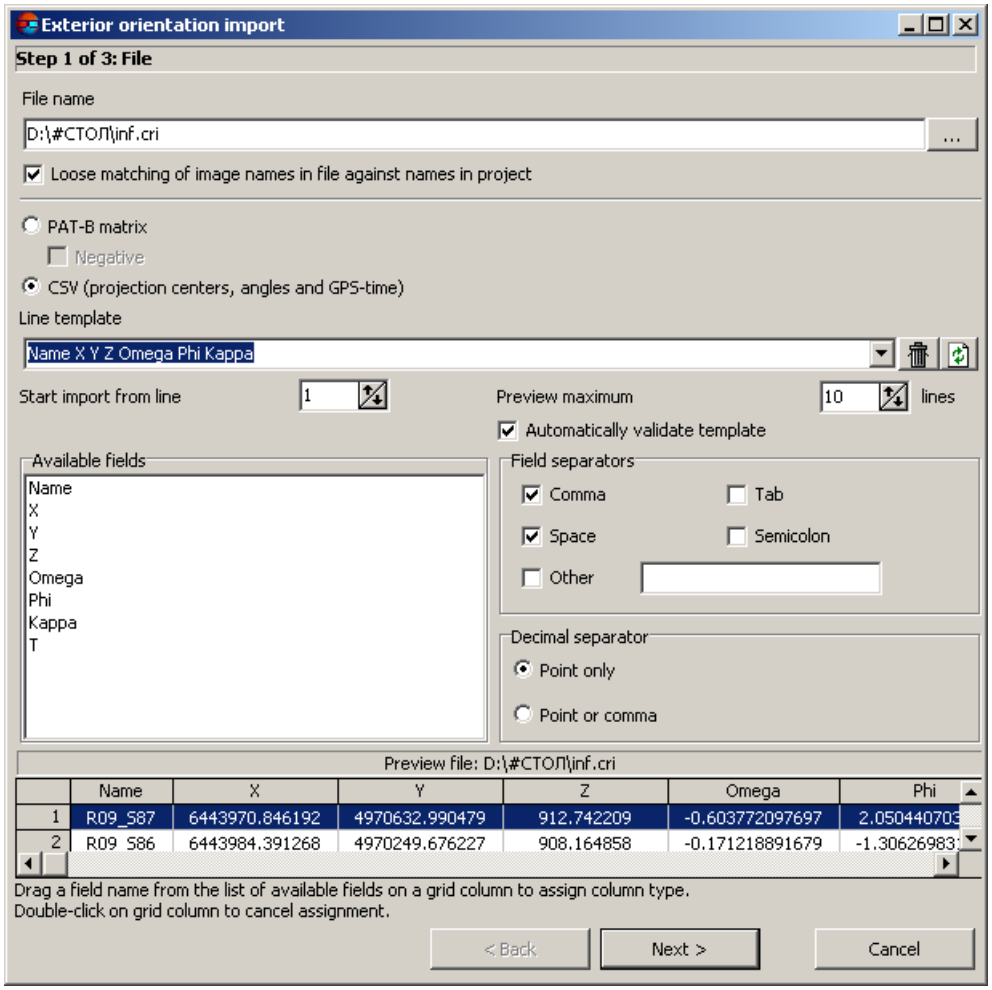
1. Import exterior orientation data (see the chapter Import exterior orientation data window, Import from UltraCam metadata and Exterior orientation data list).
2. Perform menu command **Orientation | Direct georeferencing**.
3. Perform accuracy control of exterior orientation (see the chapter Accuracy control of imported data).

Your *further actions* depend on obtained accuracy and may result in two ways – proceeding to block processing stage or performing of aerial triangulation stage (block measurement and adjustment).

5.1 *Import exterior orientation data window*

Use the **Orientation | Import exterior orientation** menu command to import external orientation data, which opens the **Open** window to select the exterior orientation data file. Having selected the file and OK pressed **Exterior orientation import** window is opened, which provides the following steps sequence:

Step 1 of 3: File



Exterior orientation data import window

The window is used to select and define the format of exterior orientation data file.

The **File name** row shows selected exterior orientation data file. To select another file press the ... button. Select the **Loose matching of image names in file against names in project** option if the names of the images in the file and in the project are not the same. In this case the system will look for common substrings and try to match the image names. For example, the common 018_02595 substring will be found in the RGBI_018_02595 image name in the file and the 018_02595 image name in the project.

Specify the exterior orientation file format:

- **PAT-B matrix** – file containing projection centers coordinates and rotation matrices. See chapter PAT-B exterior orientation import file format. Specify **Negative**, if the PAT-B file contains exterior orientation data for negative plane. Push the **Next** button to move to the window **Step 2 of 3: Import settings** (see description below).
- **CSV** – text file which can contain projection centers coordinates rotation, angles, GPS time and other data.

In the case of CSV file import it is necessary to define the import file row format.

The **Preview file** table displays data from the file being imported arranged in columns. The system tries to determine the column's types according to the template used in last flight line import procedure.

The following fields are used in the template:
Name – image name;

X,Y,Z – projection center coordinates;
Omega, Phi, Kappa – rotation angles;
T –GPS time;

The symbol * is used to mark the columns containing data not to be imported.

To display the current template which corresponds to the table data push the button (**Validate template**). The column's types and number will be defined only *for the rows displayed in the table*. The template field number will be equal to the maximum columns number in the table rows displayed.

To change the current template perform one of the following actions:
- Using mouse, drag the field name from the **Available fields** list onto the table column to define the column type. The template in the **Line template** input field will be automatically changed. Double-click on the table columns cancels the field selection.

- Change the template manually in the **Line template** input field. The table column's types are changed automatically.

The **Automatically validate template** checkbox provides automatic selection of the current template on pressing the **Next** button. So it is enough to define the table's to be imported columns types, to set the **Automatically validate template** checkbox and push the **Next** button. If the file contains rows with different columns number, unselect the **Automatically validate template** checkbox and set the template manually in the **Line template** input field.

To define the file rows number to display in the table set it in the **Preview maximum lines** input field. To define the row number to start the data import set it's number in the **Start import from line** filed.

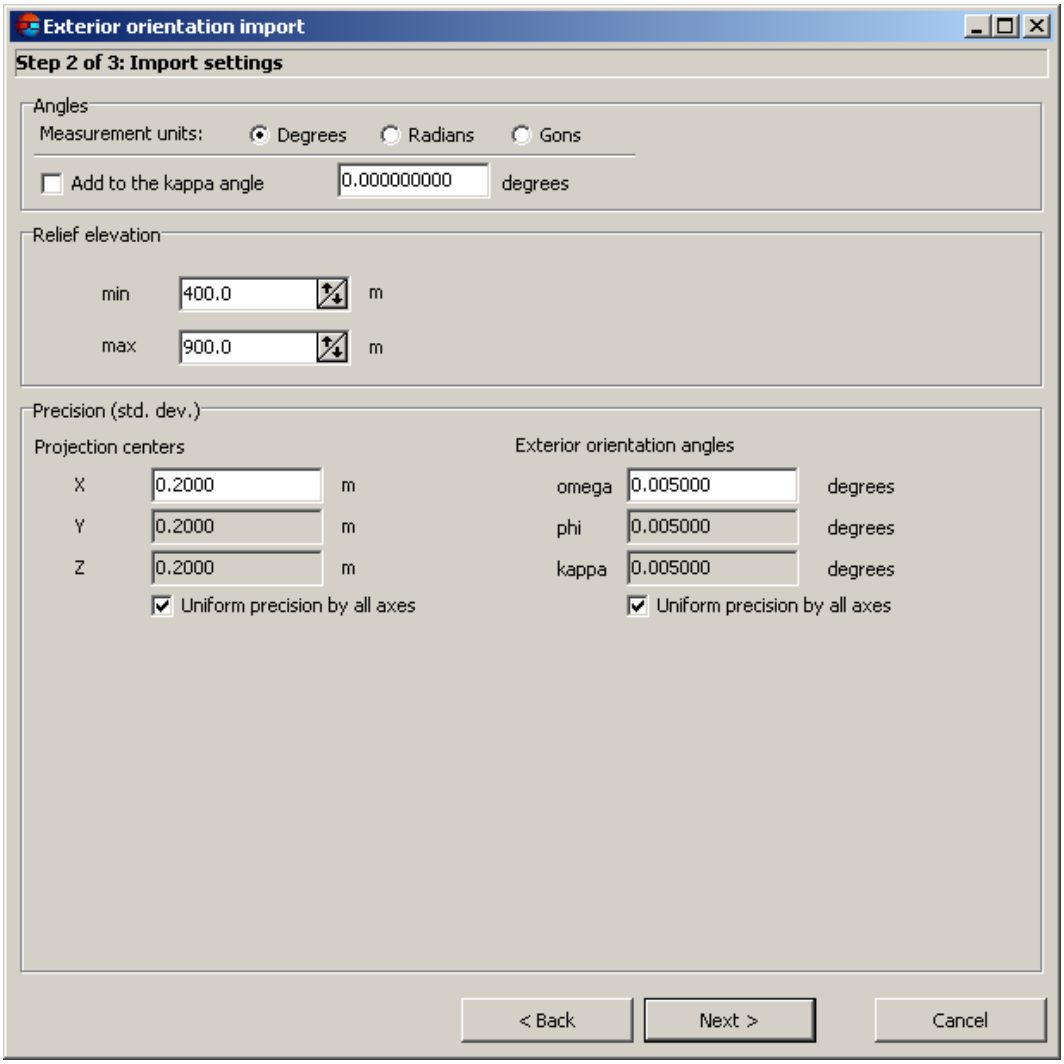
In the appropriate window sections set the file columns delimiter's type (**Comma**, **Space**, **Tab**, **Semicolon** or **Other** delimiters) and decimal delimiter for the coordinates values in the file (**Point only**, **Point or comma**)

Once the file is selected and the format is defined, click the **Next** button.

Step 2 of 3: Import settings

The window allows performing the following actions:

- To swap X and Y coordinates of the projection centers in the section **Projection centers**;
- In the section **Angles** select the same angle measurements units as in the **CSV** file – degrees, radians or grads.
- In the section **Relief elevation** specify relief height range for the project. If the data were specified during project creating they are displayed by default. Otherwise it is highly recommended to specify the relief height range to perform the import correctly.
- In the section **Precision (std. dev.)** specify the root mean square error limit for X,Y,Z – coordinates of the projection centers coordinates and omega, phi, kappa angles.



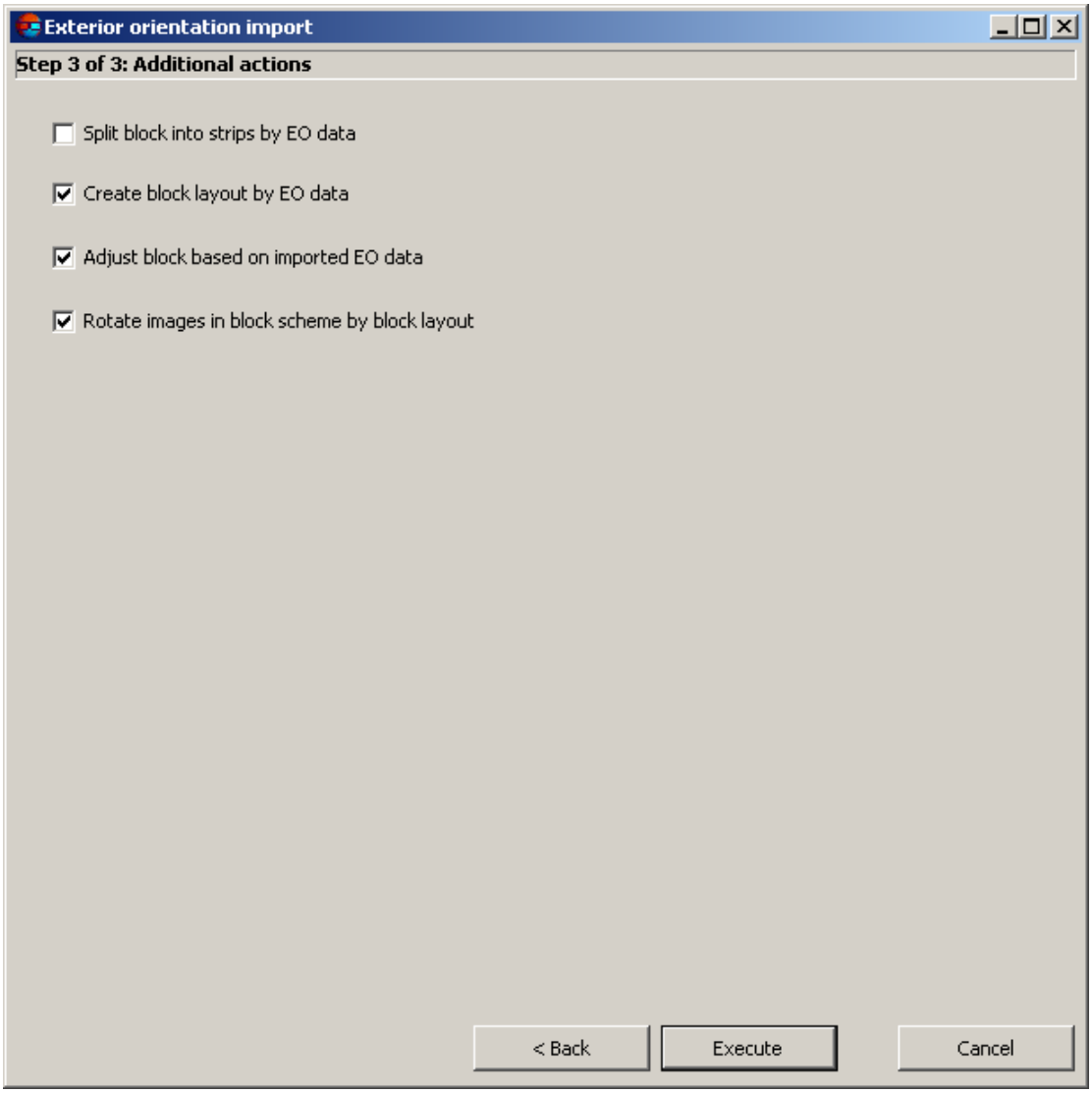
Import parameters window

Having set import parameters press the **Next** button.

Step 3 of 3: Additional actions

The window allows to define the set of target tasks ("all in one") right after the exterior orientation data import.

- **Split block into strips by EO data** – splits the images block into strips according to exterior orientation data and parameters which define the motion direction parameters through and in strips and the images GPS-times (specified in the additional window during the import). Duplicated by the **Block | Automatic block splitting | By exterior orientation data** menu command (see **Project creation** User Manual).
- **Create block layout by EO data** – creates block layout on the basis of exterior orientation data. See also the chapter Block layout.
- **Adjust block based on imported EO data** – the external orientation is performed immediately (duplicated by the **Orientation | Direct georeferencing** menu command or the button in **AT** panel)
- **Rotate images in block scheme by block layout**. Duplicated by the **Block | Rotate images by block layout** menu command (see **Project creation** User Manual).


Exterior orientation import
Step 3 of 3: Additional actions
Split block into strips by EO data
Create block layout by EO data
Adjust block based on imported EO data
Rotate images in block scheme by block layout
< Back
Execute
Cancel

Target tasks window

After import all the exterior orientation data are displayed in Exterior orientation data list. If necessary it is possible to edit them, to add new data (manually or by importing additional exterior orientation data), and then execute the **Orientation | Direct georeferencing** command (duplicated by the button) again.

After adjustment performed on the basis of the exterior orientation imported access their accuracy, for example, using ground control points. The accuracy assessment methods descriptions see in the chapter Accuracy control of imported data.

Move to the project processing stage (stereo vectorisation, DEM creating, orthorectification), if the accuracy is satisfactory. See **Project processing** User Manual. Otherwise the imported exterior orientation data are used to make the block layout for further performing the procedure of ground control/tie points measurements. Then perform the block adjustment. See also **Block Adjustment** User Manual.

5.1.1 Format of PAT-B file

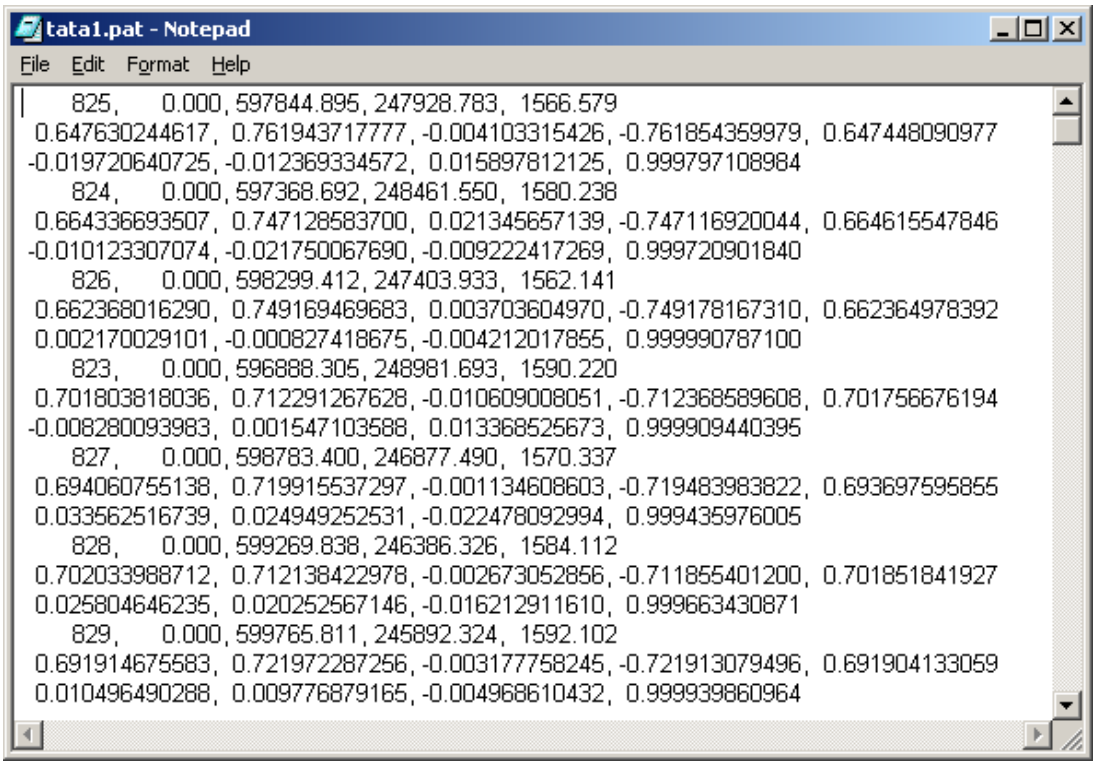
File of exterior orientation parameters (of PAT-B format) contains adjusted coordinates of projection centers and rotation matrices.

First number in each string is a number of the image, then may be zero value, and X, Y, Z coordinates of projection centers. In the next two lines are 9 values of the rotation matrix elements (3X3) – five values in the first line and four in the second. Items separator is either space or comma.

Matrix elements are calculated by following formulas and entered in following order:

a11, a21, a31, a12, a22
a32, a13, a23, a33

a11 = cos φ x cos κ
a21 = cos κ x sin φ x sin ω + cos ω x sin κ
a31 = -cos κ x sin φ x cos ω + sin ω x sin κ
a12 = -sin κ x cos φ
a22 = cos κ x cos ω – sin ω x sin φ x sin κ
a32 = sin ω x cos κ + cos ω x sin φ x sin κ
a13 = sin φ
a23 = -sin ω x cos φ
a33 = cos ω x cos φ



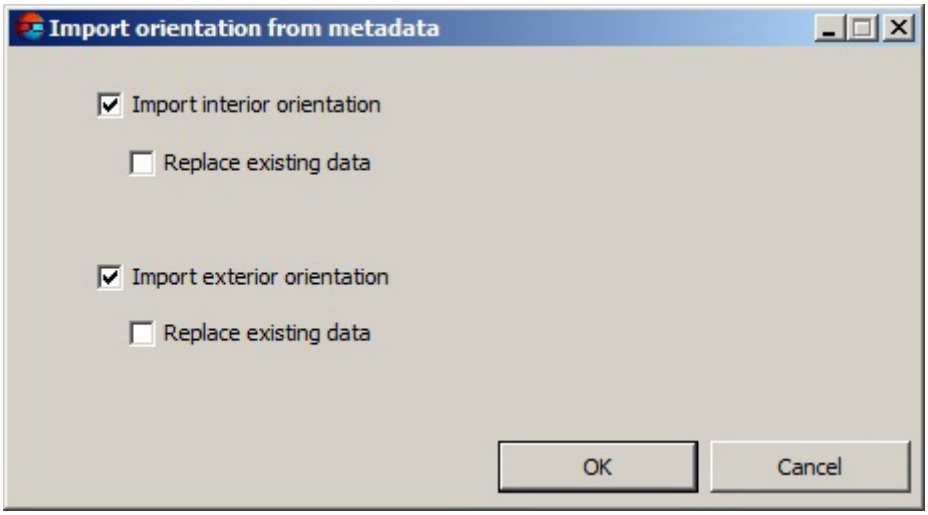
File sample with exterior orientation parameters in PAT-B format

5.2 *Import from UltraCam metadata*

If image files contain **UltraCam** metadata, files with ***.md** extension are created during images transformation to internal format using **RasterConverter** utility (see **General information** User Guide) or during images loading to project using menu command **Add images from files** (see **Project creation** User Guide). These **md**-files are placed in the same location where transformed images are located.

You can extract interior orientation and preliminary exterior orientation parameters from **md**-files for images loaded into project using menu command **Orientation | Import orientation from UltraCam metadata**. At that for each camera used in the project, camera file with name of camera's serial number is created in the project.

For exterior orientation import, it is necessary to specify *global coordinate system* and *value of heights difference of terrain* (see the chapter **New project** and **Project properties** in **Project creation** User Guide). After selecting the command, the **Import orientation from metadata** window is opened:

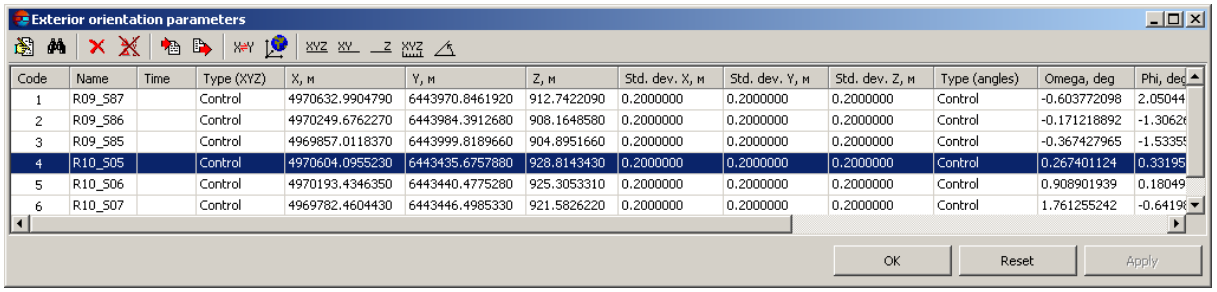


After import of orientation data from metadata, you can split a project into strips using exterior orientation (menu command **Block | Automatic block splitting | By external orientation data**), calculate rotations in block scheme (menu command **Block | Rotate images by block layout**), adjust a project using imported data (menu command **Orientation | Direct georeferencing**) and in case of satisfying accuracy (see the chapter Accuracy control of imported data) proceed to project processing stage (see **Project processing** User Guide). Otherwise, perform aerial triangulation.

5.3 *Exterior orientation data list*

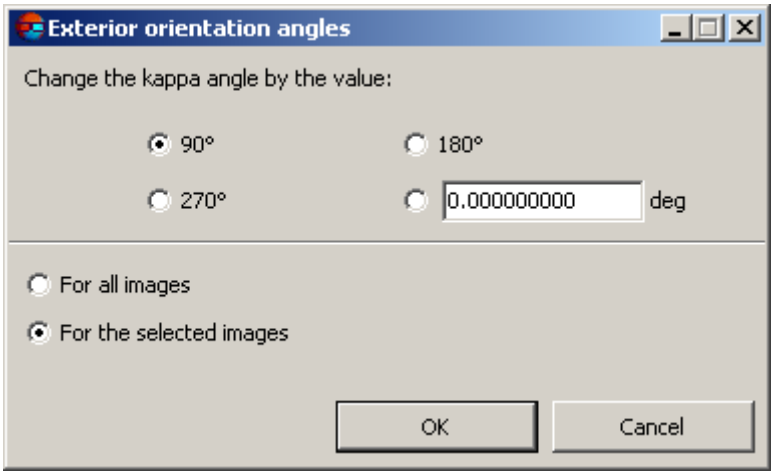
Exterior orientation data list is a list of imported or manually input exterior orientation parameters (coordinates of images projection centers, as well as omega, phi, and kappa angles that determine image position in space) and is used for input/import/edit of these data.

To open the list use menu command **Orientation | Exterior orientation data list** (duplicated by the button in the main toolbar of **PHOTOMOD Core** or in **Triangulation** toolbar). The **Exterior orientation parameters** window is opened.

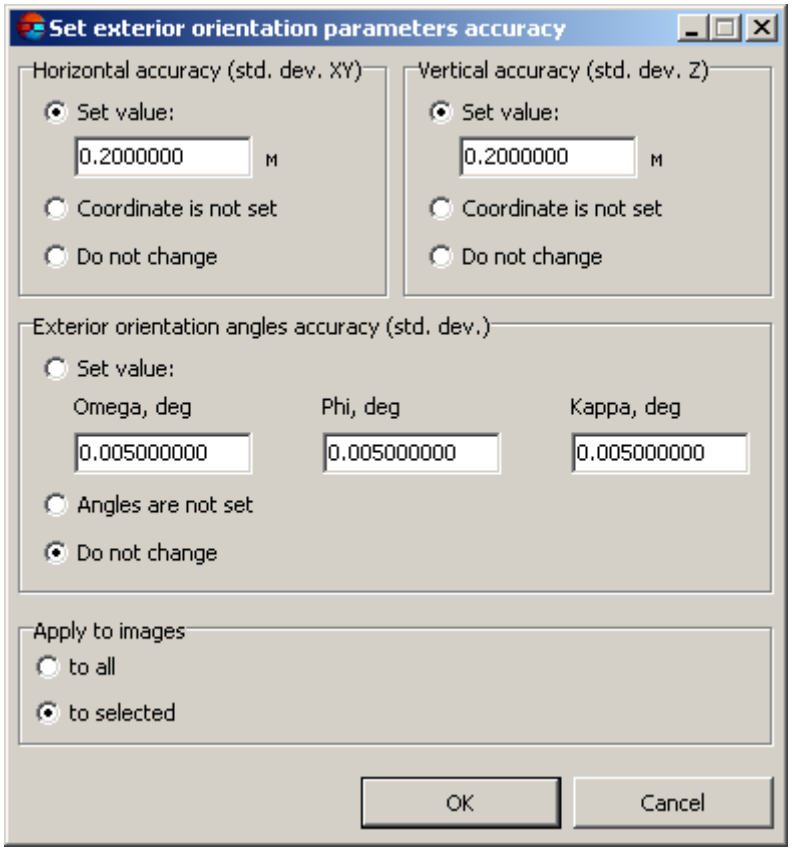


The window toolbar contains the following buttons:

- **Edit mode** – allows to edit values of list fields (**Code** and **Name** fields are inaccessible for editing).
- **Find** – opens a window for image search by its name.
- **Clear selected** – allows to delete exterior orientation parameters for images selected in the list.
- **Clear all** – allows to clear the entire list.
- **Import** – opens the **Import exterior orientation data** window, see the chapter Import of exterior orientation parameters.
- **Export** – allows to export the list with exterior orientation parameters to text files (**.csv** and **.txt**).
- **Swap X and Y** – allows to swap coordinates values in X and Y columns for selected or for all images, if necessary.
- **Convert into another coordinate system** – opens the **Convert coordinate system** window, where you can select different coordinate system for selected or for all images.
- **Set type of selected: XYZ** – enables three coordinates X,Y,Z of projection centers of all selected images in case if any of the coordinates would be excluded.
- **Set type of selected: XY** – excludes Z-coordinate of projection centers of all selected images. The value of excluded coordinate is indicated with grey color and its field is available for editing. After editing, the value of excluded coordinate will be linked automatically (will be used).
- **Set type of selected: Z** – excludes X,Y- coordinates of projection centers of all selected images. The values of excluded coordinates are indicated with grey color and their fields are available for editing. After editing, the values of excluded coordinates will be linked automatically (will be counted).
- **Set exterior orientation parameters accuracy** – opens the **Set exterior orientation parameters accuracy** window to set acceptable threshold of RMS error in XY-plane and by Z-axis in meters, and exterior orientation angles accuracy for all or for selected images.
- **Change the kappa angle** – allows to change kappa angle by specified value for all or for selected images. Click the button to open the **Exterior orientation angles** window:



There is a connection between **Exterior orientation parameters** window and **2D window**, i.e. images highlighted in block scheme are automatically selected in the list of **Exterior orientation parameters** window, and vice versa, when images are selected in the list, they are highlighted in block scheme in **2D window**.



5.4 *Accuracy control of imported data*

In order to make a decision about further actions after import of exterior orientation data you should estimate accuracy of obtained results of exterior orientation. You can perform accuracy control using the following ways:

- *By block layout.* Visual estimation of block layout, created using exterior orientation data (see the chapter Block layout creation), allows to detect blunders in block scheme. However, you should remember that block scheme creation by exterior orientation, beside imported data, depends on such important conditions as absence

of interior orientation errors and availability of a value of height step of surveyed terrain. Both parameters are setup during project creation in project settings (see **Project creation** User Guide) or in Import exterior orientation data window). If you are satisfied with visual evaluation, you can adjust the block scheme by GCP coordinates or by Y-parallax in stereo mode.

- *By ground control (check) points coordinates*. You can estimate accuracy by GCP coordinates using two following ways:
  1. Measure several GCP and analyze errors in **Block adjustment** window. For that after import of exterior orientation parameters, measure several GCP on block images (see the chapter Input and measuring of ground control points). Then perform menu command **Orientation | Direct georeferencing** once more and open **Block adjustment** window (using menu command **Orientation | Block adjustment** or the button) to view GCP error vectors on block scheme and analyze errors in the report. See also **Block adjustment** User Guide.
  2. Analyze marker coordinates (displayed in status line) in location of ground control point on block images in 2D-window.

- *By Y-parallax in stereo mode.* For that after import of exterior orientation parameters you should:
  – measure several (6-10) tie points on block images (see the chapter Relative orientation and ground control points measurement)
  – perform menu command **Orientation | Direct georeferencing** once more
  – open Points measurement module and estimate a value of Y-parallax (displayed in the upper right corner of the window) on tie points *in stereo mode*. At that you should click the button **Create epipolar images using adjustment results** (see the chapter Points measurement in stereomode). You can also use mono mode for errors evaluation on triangulation points using the buttons (**Show GCP error vectors**) and (**Show tie error vectors**) of the mail toolbar of the Points measurement module window.

6. Block layout

6.1 *Data for block layout creation*

Block layout – approximate terrain scheme (block scheme later on), obtained by projecting of assembled images block on specified surface (ground surface) considering images overlap, their relative location, and their spatial turn angles.

Depending on a data set used for block layout creation, the block layout may be *initial*, approximate or final. I.e. as data is collecting and involving into block layout creation, the block scheme becomes more accurate. And after applying of correct adjustment results, the block layout grows into final block scheme of project images.

Block layout is shown in the **2D** window and is used for visual estimation of terrain images location. Besides, block layout (*initial*, at least) is compulsory condition for automatic tie points measurement. See the chapter Automatic tie points measurement.

The following data may be used for block layout creation (the data is listed in order of increasing accuracy of a block layout):

- Size of overlap area of adjacent images in a strip and between strips. Usually images overlaps in percent are known or may be estimated by images matching using the same terrain spots. Overlaps are used for 'rough' approximation of a block scheme, i.e. for creating of initial block layout.

- Data of images manual matching. Manual matching data is also used for creating of *initial* block layout; however, they can significantly refine a block scheme, built 'by overlaps'. In order to get manual matching data you should match images manually by approximate specifying of the same terrain spots on adjacent images on a block scheme in the **2D** window. See the chapter Manual matching of images.

- Tie points. For tie points collecting you should measure the same terrain points on images with predefined accuracy in automatic mode or manually in the **Points measurement** module. Accuracy of relative images location on a block layout depends on the measurement accuracy and tie points number. For example, for *initial* block layout you may measure a few ties between images and use them instead of manual matching data for more accurate matching. As 'precisely measured' tie points are collecting, the block layout accuracy is increasing. See the chapters Automatic tie points measurement and Manual measuring of triangulation points.

- GCP (if available). For using of GCP for block layout creation, input their coordinates and measure them on images of a block in the **Points measurement** module. Block layout created by GCP, represents a block scheme in a real coordinate system. See the chapter Input and measuring of ground control points.

- Exterior orientation parameters (if available) – *projection centers coordinates and three angles*, which define in total a real location of images in space. You should import exterior orientation parameters into PHOTOMOD system to use them for block layout creation. Block layout created using exterior orientation parameters, is images projection considering real coordinates of projection centers and rotation angles. See the chapter Import of exterior orientation data.

- Block adjustment results. Perform block adjustment (if there is data enough). Block layout created using adjustment results, represents a final block scheme with coordinates' accuracy, obtained on the adjustment stage. See **Block adjustment** User Guide.

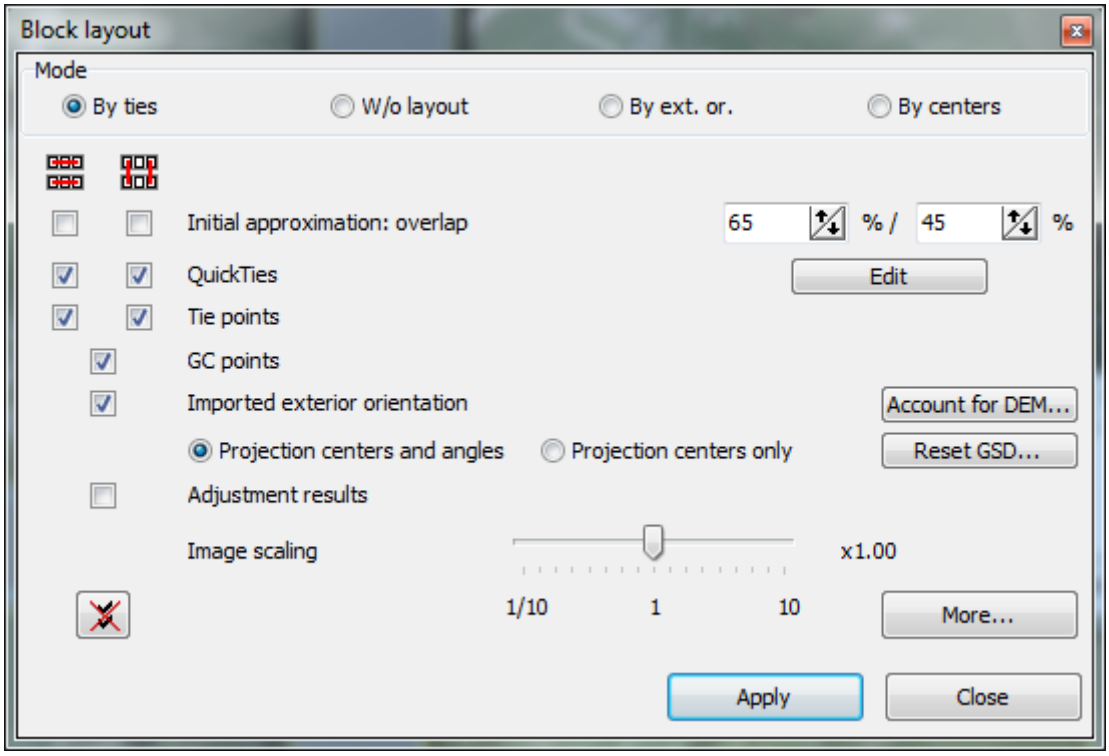
- (optional) Digital elevation model (DEM) or ground pixel size (GSD) (if available). Block layout is created considering pixel size on terrain (GSD), specified by a user or calculated automatically from DEM data. GSD influences on images sizes during block layout creation. See the chapter Using DEM data for block layout creation.

6.2 *Block layout creation*

Perform the following actions to create a block layout:

1. Collect and define data to be used for block layout creation. See the chapter Data for block layout creation.

2. Choose **Windows | Block layout** or click the button of the main toolbar. The **Block layout** window is opened.



Parameters of block layout creation

3. In the **Mode** panel choose one out of three modes of block layout creation or without block layout mode.
Note: During block layout creation it is recommended to use first of all exterior orientation parameters (if any). See the chapter Import of exterior orientation data. Block layout creation considering exterior orientation parameters may considerably reduce processing time on aerial triangulation and relative orientation stages, and even skip block adjustment, in case of satisfactory accuracy. If a block layout created using exterior orientation parameters is visually acceptable, we recommend to perform accuracy control by GCP coordinates and/or by Y-parallax values during measurement of several tie points (for more accurate estimate). If the accuracy is acceptable, you can skip block adjustment stage, perform direct georeferencing, and pass to project processing operations (stereo vectorization, DEM building, mosaic creation). See the chapter Workflow. Otherwise, measure GCP/tie points to refine a block layout, and then perform block adjustment stage.

Brief description of block layout creation modes

Mode	Description
By ties	The mode allows to define a data set, that will be used in block layout creation. All parameters of the **Block layout** window are available in this mode. Please see below a description of the **By ties** mode parameters.
W/o layout	The mode allows to cancel block layout creation and to roll back to initial block scheme view. All parameters of the **Block layout** window are unavailable in this mode.
By ext.or.	The mode allows to use *only* exterior orientation data (projection centers coordinates and rotation angles) for block layout creation (when imported exterior orientation data is available). The rest of data is not used. In this mode only functions of image scaling and DEM using are available.
By centers	The mode allows to use projection centers coordinates of images for block layout creation (when imported exterior orientation data is available). You can refine block layout, created by images centers coordinates, as other data is collected, using the **Refresh block**

	layout button of the **Block layout** toolbar, however projection centers data will underlie. In this mode only functions of image scaling and DEM using are available. ***Note: The By centers mode is used for block scheme creation using UAV images.***

4. Set up the parameters of chosen mode. Main parameters of block layout creation are available only in the **By ties** mode.

Parameters of the **By ties** mode

Parameters	Description
Initial approximation: overlap	Allows to set in-strip and inter-strip overlaps in percent, If images and strips overlap size is almost the same for the entire block. If overlap sizes for the block images and strips is not the same or not very precise, use another way for block layout creating, for example, manual matching of images. Overlap size is used for a block layout first approximation – *initial* block layout.
QuickTies	Allows to use manually linked QuickTies data, collected by approximate specifying (accurate within about some hundreds of pixels) of the same terrain spots on adjacent images on block scheme in the **2D** window. We recommend to set at least two ties on each stereopair and two ties between strips of a block. Click the **Edit** button to start creating/editing of manual ties in the **QuickTies** layer. See the chapter Manual matching of images.
Tie points	Allows to use tie points measured in automatic or manual mode (see the chapters Automatic tie points measurement and Manual measuring of triangulation points). The more precisely measured the ties, the more accurate is the block layout. For initial block layout you can measure some number of tie points between in-strip and inter-strip images instead of images manual matching, which provides more accurate images tying in a block scheme.
GC points	Allows to use preliminary measured GCP. Block layout created by GCP represents block scheme in a real coordinate system. See the chapter Input and measuring of ground control points.
Imported exterior orientation	Allows to use exterior orientation parameters (if any), imported to PHOTOMOD system in advance (see the chapter Import of exterior orientation data). You can select only projection centers and angles or just projection centers. Block layout created by projection centers and angles is images projection considering real coordinates of images centers and rotation angles. ***Note: Projection centers and angles values are used in block layout creating along with other data selected (in contrast to the By ext.or. mode, that considers only exterior orientation parameters).***
Adjustment results	Allows to use adjustment results, if it is possible to perform block adjustment. Block layout created by block adjustment results is a final block scheme of project images. ***Note: When you use adjustment results along with other data for block layout creation, the adjustment results take priority in this case. I.e. if some block images have no adjustment results, so other data, selected in the Block layout window, will be used during block layout creation. Otherwise, the other data is ignored and only adjustment results are considered.***

For all modes of block layout creation the following functions are available (with some limitations):

- Images' scaling in a block layout, with help of the Image scaling slider, is used for visual estimate of images location without overlap.

- Considering the ground pixel size (GSD), specified by a user or automatically calculated by DEM (if any). Click the **Account for DEM** button to specify GSD parameters. See the chapter Using DEM data for block layout creation.

Warning: You should have interior and exterior (projection centers coordinates, at least) orientation parameters available to calculate GSD by DEM.

Warning: When ties/GCP or adjustment results are used for block layout creation, GSD data is not considered.

- Considering value of terrain heights difference, specified in the project properties (see **Project creation** User Guide).

Warning: heights difference value is considered for block layout creation only if GSD data is unavailable.

5. In order to eliminate specific issues, called by improper input data, click the **More** button. The **Block layout (additional)** window, containing the following additional parameters, is opened:
   - **Scale difference** – used to specify a coefficient proportionate to acceptable scale difference between adjacent images in a strip;
   - **Curving** – used to specify a coefficient proportionate to acceptable rotation angle between adjacent images in a strip;
   - **Images deformation** – used to specify acceptable difference between image outline transformation in a block scheme and similarity transformation;
   - **Point rejection percent** – used to specify percent of tie points, which will be not considered for block layout creation;
   - **Rotate all block by** – used to specify rotation angle for block scheme in degrees.

6. For block layout creation click the **Apply** button in the **Block layout** window. Block scheme in the **2D** window will be refreshed considering new parameters settings (without closing of the **Block layout** window). You can also use the following menu items **Block | Block layout** for creation/re-creation of a block layout (they are partially duplicated by buttons of the **Block layout** toolbar):
   - **Refresh** – allows fast block layout re-creation after change of data used for block layout building (without opening of the **Block layout** window). Duplicates clicking of the **Apply** button in the **Block layout** window.
   - **W/o layout** – allows to cancel block layout creation, i.e. rolls back to initial state of block scheme (without opening of the **Block layout** window). Duplicates choosing of the **W/o layout** mode in the **Block layout** window.
   - **By exterior orientation** – allows to create a block layout using *only* exterior orientation parameters imported to PHOTOMOD system (without opening of the **Block layout** window). Duplicates choosing the **By ext.or.** mode in the **Block layout** window.
   - **Load** – allows to load saved block layout from *.x-ini file of active profile resources to the **2D** window.
   - **Save** – allows to save current block layout to *.x-ini file of active profile resources. You can use the saved block layout, if after applying of new data the block layout corrupted and fails to recover. In this case you can load the block layout, delete triangulation points and measure them once more.
   - **Automatic block layout** – allows to create block layout of UAV images in automatic mode.
   - **Delete auto block layout results** – allows to cancel block layout, created for UAV images in automatic mode.

6.3 *Using DEM data for block layout creation*

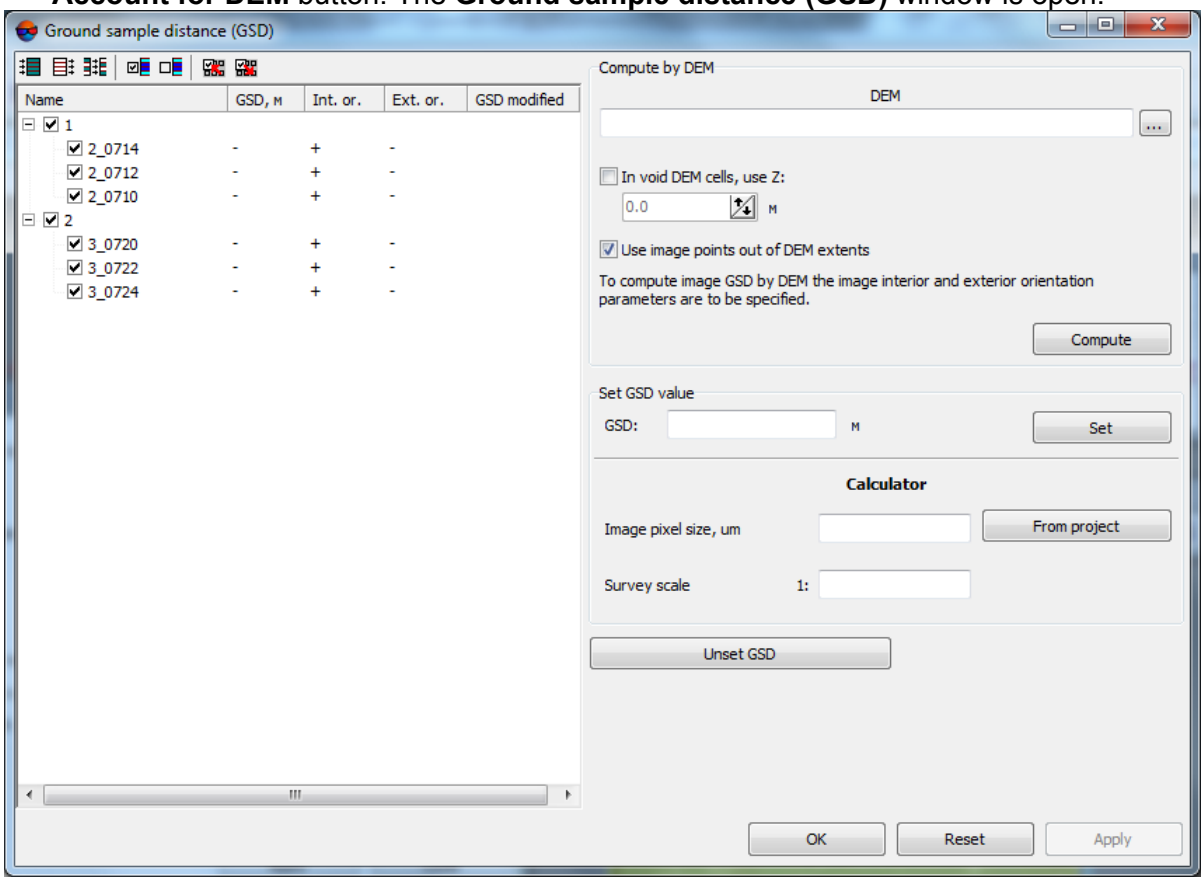
For block layout creation you can use a value of *ground pixel size* (GSD), specified manually or calculated automatically by DEM. GSD value has an influence on a size of block images.

Warning: You should have interior and exterior (projection centers coordinates, at least) orientation parameters available to calculate GSD by DEM. See the chapter Import of exterior orientation data.

Warning: When ties/GCP or adjustment results are used for block layout creation, GSD data is not considered.

For block layout creation using GSD, calculated automatically by DEM or specified manually, perform the following actions:

1. Open the **Block layout** window (see the chapter Block layout creation) and click the **Account for DEM** button. The **Ground sample distance (GSD)** window is open.



Defining of GSD using DEM or manually

2. View GSD values in the appropriate table column and select images, for which you will specify GSD values.

Table column	Description
Name	This column shows names of all strips and images of a block.
GSD, m	This column shows current GSD value (if there is no GSD data, the "-" symbol is shown). ***Note: User may set up GSD data for images on a previous stage of block forming, using the* Block | Set GSD *menu.***
Interior or.	This column shows interior orientation parameters availability for images of a block: "**+**" – available, "**-**" – unavailable. ***Note: For GSD calculation by DEM you should have interior orientation parameters available.***
Ext. or.	This column shows *availability* of imported exterior orientation data for

	images of a block: "**+**" – exterior orientation data is available, "**-**" – no ext. or. data available. ***Note: For GSD calculation by DEM you should have at least, projection centers coordinates available.***

3. To calculate GSD value for selected images perform one of the following:
   - Specify DEM for automatic GSD calculating in the **Compute by DEM** panel. Set the **In void DEM cells, use Z** checkbox if necessary, and specify Z-coordinate in the input field for DEM empty cells (if any). Set the **Use image points out of DEM extents** checkbox, if DEM does not fully cover images block. Click the **Compute** button. GSD values calculated by DEM for selected images are shown in the table.
   - Specify GSD value manually or calculate using calculator in the **Set GSD value** panel. Prior to use calculator detect image pixel size in micron (manually or from project data by clicking the **From project** button) and survey scale. After that the **GSD** input field is updated automatically. When the **GSD** input field is filled click the **Set** button. The GSD value is shown in the table for selected images.
   - You can clear GSD values by clicking the **Unset GSD** button. After that the GSD column in the images table will contain "**-**" symbol.
4. Click the **Apply** button to save acquired GSD values.
5. For block layout creation using GSD data click OK in the **Ground sample distance (GSD)** window, and then click the **Apply** button in the **Block layout** window. The block scheme will be re-created considering specified GSD data, if ties/GCP and adjustment results are not used for block layout creation.

Note: If the GSD data is not available during block layout creation you can use the value of terrain heights difference, specified in the project properties (see Project creation User Guide).

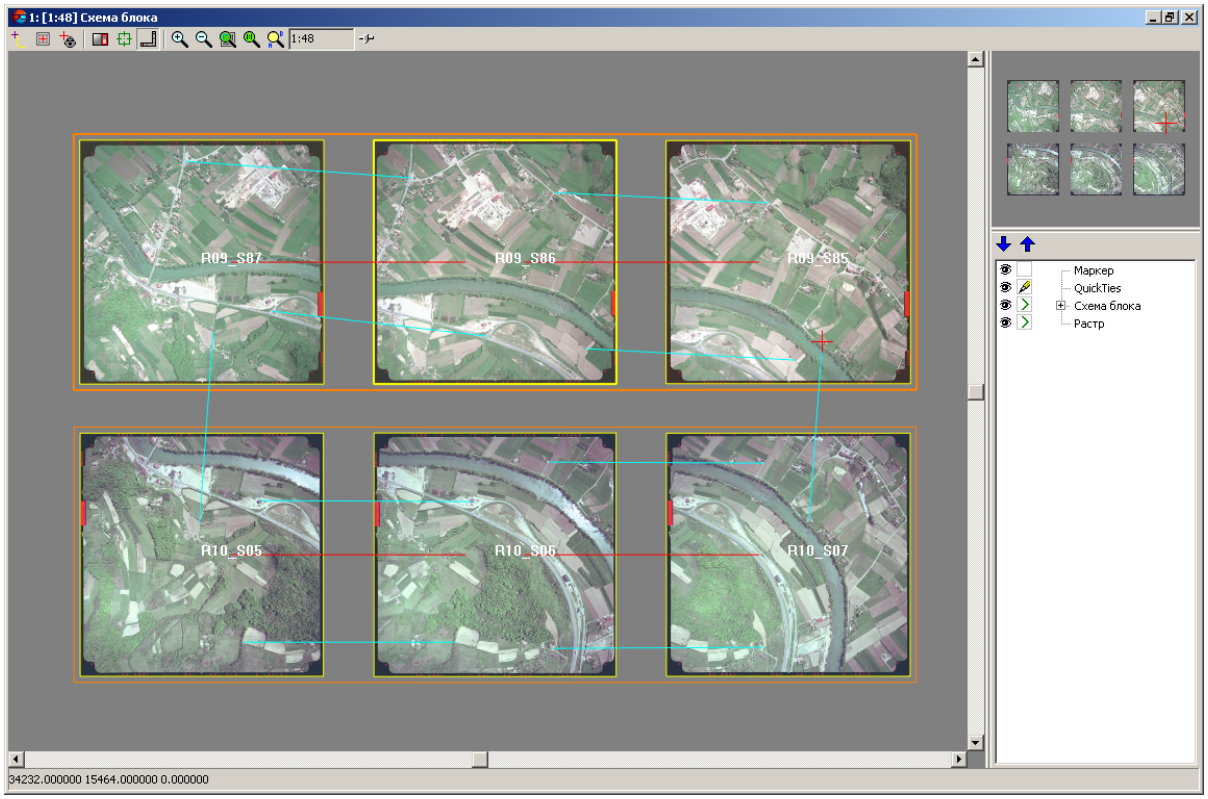
6.4 *Manual matching of images*

Data of manual images matching is used for *initial* block layout building. Manual matching means manual collating of images by approximate identifying (with accuracy at least of several hundreds of pixels) of two pairs of corresponding points for each pair of adjacent images in **2D** window.

During manual matching operation you should consider the following recommendations:

1. At first it is recommended to match all images with each other in a strip, and then to match strips with each other.
2. It is recommended to set *at least* two "links" for each stereopair and two "links" between strips.
3. Pairs of the same points should be selected in different parts of images in strips.

Note: If there are precise and constant enough overlap areas within images block, it is necessary to have a little manual matching data for block scheme refinement. For example, if overlap area between stereopairs in all strips is constant, you can match only strips.



Manual matching of images

Manual matching procedure includes the following actions:

1. Choose **Orientation | QuickTies | Edit** (duplicates the **Edit** button in the **Block scheme** window). After that the *QuickTies* active layer is created in the Layer manager.
2. Set/edit links between images using the following way:
   - To link two points on the images place marker to selected terrain point of the first image and press **Insert**, then place the marker to corresponding terrain point of the second image (rubber line appears directing from the first point to the second) and press **Insert** again. Links added are shown in the **2D** window by blue lines.
   - To cancel added link after specifying the first point, press the **Esc** key, at that the rubber line disappears.
   - To delete a single link, select it by double click or by pressing the **S** key. The line linking matching points becomes yellow and you can click **Delete** to delete it. To delete multiple links use group selection tools in the appropriate toolbar.
   - To delete all manual matching data choose **Orientation | QuickTies | Clear**.
3. Choose **Orientation | QuickTies | Save** to save manual matching data.
   Note: manual matching data is saved automatically after block layout creation and at the end of PHOTOMOD session.

7. Project types

PHOTOMOD system allows creating the following types of projects (depending on type of processed images): **Central projection** (to process aerial or space images, obtained by photo camera) and **Scanner survey** (to process space images, obtained by scanner IKONOS, QuickBird, GeoEye, WorldView, SPOT, ASTER, IRS, Resours-DK etc.). You can select a project type during the project creation (see **Project creation** User Guide).

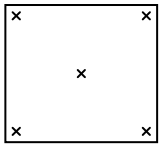
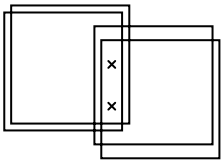
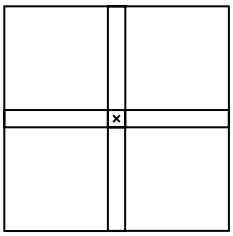
When processing central projection images (obtained by photo camera) **PHOTOMOD** system works with images blocks. For blocks of images you may perform total photogrammetric processing.

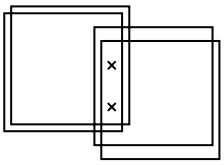
Projects of **Satellite scanner imagery** type have two subtypes – depending on survey type, you can create in **PHOTOMOD** system *monoblocks* or *stereoblocks* of space images. If a set of images is not a stereo product, i.e. the images do not form a real stereopair, then the images block is called *monoblock* and it should be input as usual with dividing into separate strips. Single satellite image is also considered as a monoblock.

If two adjacent images are combined into a stereopair and/or there are several such stereopairs, then each stereopair should be input as a separate strip. Images block formed by such stereopairs is called *stereoblock*. See **Project creation** User Guide.

In case of stereoblock you can perform full photogrammetric processing.
When process scanner images monoblock you can perform measurement of ground control points and interstrip ties.

7.1 *Number of GCP recommended for relative orientation of space images*

Project type / **Algorithm**		**Monoblock**	**Stereoblock** (strips with stereopairs)
Rigorous	Number of GCP	**Number of GCP's per image:** *Resours-DK* – 6 *FORMOSAT-2* – 4-6 *EROS A,B* – 4-6 *KOMPSAT-2* – 4-6 *SPOT 1-4* – 4-6 *SPOT 5* – 4 *TERRA/ASTER* – 4-6 	**Number of GCP's per stereopair:** 4-5 GCP per image (their number could be less if tie points measured in triple or quadruple overlap are used) 
	Number of check points	3-5	1-2 (not less than 5 for block)
	Number of tie points	3-4 points in double overlap area, if there is triple or quadruple overlap – measure some points there 	3-4 in quadruple overlap
RPC	Number of GCP	**Number of GCP's per image:** *QuickBird* - 1-4 *OrbView-3* – 1-4 *WorldView-1* – 1-4 *GeoEye-1* – 1-4 *IKONOS* - 1-4	**Number of GCP's per stereopair:** *GeoEye-1* – 1-4 *IKONOS* - 1-4 *KOMPSAT-2* – 4-5 *Cartosat-1 (IRS P5)* – 4-5 *ALOS (PRISM)* – 1-4

		KOMPSAT-2 – 4-5 *Cartosat-1 (IRS P5)* – 4-5 *ALOS (PRISM) – 1-4*	(points number could be less if tie points measured in quadruple overlap are used) 
	Number of check points	3-5	1-2 (not less than 5 for block)
	Number of tie points	3-4 points in the images twofold overlapping area	3-4 in quadruple overlap
Generic	Number of GCP	**Number of GCP's per image:** *Landsat 7/ETM+* *IRS-1C, 1D/PAN* *IRS P6 (Resourcesat-1)* *ALOS (AVNIR 2)* – 7-10 - minimum with which you can start adjustment	**Number of GCP's per stereopair:** *Landsat 7/ETM+* *IRS-1C, 1D/PAN* *IRS P6 (Resourcesat-1)* *ALOS (AVNIR 2)* – 7-10 - minimum with which you can start adjustment
	Number of check points	5-7	5-7
	Number of tie points	Could be not measured	Could be not measured

Note: The recommended number of GCP's in the table is not absolute and in many cases may be determined by the requirements to a particular project from the customer. Nevertheless, we can say that the presence of check points is necessary for an objective assessment of the accuracy of adjustment.